FSE PROGRAM SUMMARY DOCUMENT #1

TRIM

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Title: TRIM

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Function: General purpose regression analysis routine, applicable to aircraft trimming processes.

Language: FORTRAN, Computer Portable, ANSI Standard

References: (1) "BQUIET, A Six-Degrees-of-Freedom Trim Process Fully Integrated The BASIC System", NASO 72-12, Nov. 1972 (Computer Sciences Corp.)
(2) "Trimming an Aircraft Model for Flight Simulation", NASA TM 89466, Oct. 1987.

Summary: Subroutine TRIM will trim up to 10 arbitrary states to selected values and to within selected tolerances, by manipulation of up to 10 arbitrary controls. If more controls than states are used, the method of Lagrange multipliers is used. If less controls than states are used, the least squares method is used.

TRIM evaluates partial derivatives once each IREVAL "primary evaluation cycles." Sometimes the initial flight regime partials are mathematically sufficient for the iterative trimming solution to a multidimensional rotorcraft trimming problem, meaning that IREVAL may be large.

After evaluation of the partial derivatives, the procedure reverts to the directional derivative technique, during which all influence coefficients are used. These coefficients are the elements of the pseudo-inverse matrix, which has NCONT rows, where NCONT is the number of controls, and NSTATE columns, where NSTATE is the number of states.

Subroutine TRIM works well on problems not well accommodated by other FS software. It is about eight times faster than BQUIET because partial derivatives are not continually reevaluated. It is usually faster than GENTRM6. It does not require a priori knowledge of influence coefficients.

Acceptance is based on two vector criteria: The states are at selected values, to within selected tolerances, and the controls have become quiescent.

Internal filters are used without influencing the model states. These filters permit the trimming of a typical blade-element rotorcraft model in less than ten seconds, at any point in the flight envelope.

The program listing is presented at the end of this document.

Calling Sequence:

```
      CALL TRIM(NCONT,C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,
     1          BOTVKT,TOPVKT,
     2          NSTATE,S1,S2,S3,S4,S5,S6,S7,S8,S9,S10,
     3          DESVKT,ACPVKT)
```

Calling Sequence Definitions:

NCONT The number of controls. $1 \leq NCONT \leq 10$

C1 - C10 Control identifiers. Any quantities available to the calling program which may be controlled by subroutine TRIM, and which influence at least one state. Controls are used within TRIM as outputs as well as inputs. Since usual controls include pilot inputs, analog-to-digital channels (A/D's) should be inhibited during trim. Subroutine TRIM retains complete command of the controls while ITRMCM = 1.

BOTVKT(I) A vector containing the minimum control excursions, in the order of the calling sequence, and of length (dimension) NCONT or greater (up to 10).

TOPVKT(I) A vector containing the maximum control excursions, in the order of the calling sequence, and of length (dimension) NCONT or greater (up to 10).

NSTATE The number of states to be trimmed to the DESVKT(I) values, and to within the ACPVKT(I) tolerance acceptance limits. $1 \leq NSTATE \leq 10$

S1 - S10 State identifiers. Any quantities available to the calling program are permitted providing that they are influenced by at least one control. These are used only as inputs by TRIM.

DESVKT(I) A vector containing the desired final state values (usually zeros are desired), in the order of the TRIM calling sequence, and of length (dimension) NSTATE or greater (up to 10).

ACPVKT(I) The acceptance tolerance vector for the states (half the total bandwidth of acceptance). A vector containing the (positive) acceptance values of the states minus their desired values (absolute value) in the units of the individual states, for automatic trim determination. Dimensioned NSTATE or greater (up to 10).

Features

Subroutine TRIM replaces subroutines BQUIET and GENTRM6. Previous trimming routines at the Ames Simulation Laboratory contain subset features of subroutine TRIM:

(1) Up to 10 controls are permitted;

(2) Up to 10 states are permitted;

(3) The number of states may be greater than, equal to, or less than the number of controls (overdetermined as well as determined and underdetermined);

(4) The desired final values of the states are selected by the calling program, in the units of the states;

(5) The tolerance values (acceptance criteria) are selected by the calling program, in the units of the states;

(6) All "shell logic" and screen messages are internal to TRIM;

(7) Messages appear on the screen whenever controls hit limits (and bounce off);

(8) The controlling switch (ITRMCM) is automatically reset when the state acceptance criteria are met, and when all control variations (from one evaluation to the next) display changes of less than one tenth of one percent of their range;

(9) The matrix inversion process is internal to TRIM, and occurs once per complete trim procedure (every NDELAY*NCONT cycles - a primary evaluation interval), if IREVAL = 1. IREVAL should usually be much larger than unity, so that inversion is then performed only every IREVAL*NDELAY*NCONT intervals.

(10) Immediate termination is featured when ITRMCM is manually reset (in which case IMANTR is set by TRIM), or when the trim criteria are met as determined by TRIM (in which case IMANTR is reset);

(11) When TRIM senses that the aircraft is not airborne (IHIT = 1), the calling sequence is ignored and a special process takes over. This process determines the three quantities THETIC, HIC and PHIIC, which are the aircraft pitch angle, altitude and roll angle. These three quantities, required for rotorcraft ground trim, communicate with the model through standardized channels. Four quantities are automatically nulled: PBD, QBD, WBD and VBD, which are the aircraft roll acceleration, pitch acceleration, vertical acceleration, and lateral acceleration. GAMVIC = 0 is provided as a service in this mode of operation. (The use of a slanted runway requires a modification to this feature);

(12) A first-order filter is activated to generate pseudo-states within TRIM (actual states are not changed by TRIM). These quantities, which change each cycle, are available in the special COMMON buffer. The continually-running filter has a time constant of one-fourth the product of the cycle time and NDELAY. The final outputs of this filter after (each) NDELAY cycles are used for both secondary and primary evaluations;

(13) The states are of special interest every NDELAY cycles, when IEVAL is set. At this point, with an appropriately large enough value for NDELAY, a sufficient number of intervals should have transpired in the model to produce state quiescence after control changes. Initially, the controls are consecutively perturbed (through each IPARTE control), and this process terminates with a primary evaluation, where IPARTE = 0, at which point a total control vector change is made (this defines a "primary evaluation interval"). The primary evaluation interval then becomes only NDELAY cycles if IREVAL is greater than one, and this lasts for NDELAY*IREVAL cycles.

The availability of IEVAL to the calling program permits the tracking of the partial evaluation progress without transient interference, if desired. The value for IPARTE remains in the reset condition after the partials have been evaluated until IREVAL primary evaluation cycles transpire. During this interval IEVAL continues to be set every NDELAY cycles, for one cycle;

(14) Manual termination (resetting ITRMCM) terminates TRIM with the controls returned to the most recent primary evaluation point, and IMANTR = 1;

(15) TRIM requires only subroutine BTYPE. A non-real-time version of BTYPE is available in the STRIKE account. Thanks to J. Bunnell, this program has only one

executable line of code. Real-time users have unique versions of this software for each computer installation;

(16) Trimming with subroutine TRIM, after the partials are evaluated, appears much like trimming with subroutine GENTRM6, except that influence coefficients are computed by TRIM rather than being required inputs, and they are computed automatically. Also, because all of the influence coefficients (NCONT*NSTATE) are computed, the user is not required to establish control/state dependency a priori.

(17) A "noisy environment" does not adversely influence subroutine TRIM, as previously occurred using subroutine BQUIET. Noise or high frequency harmonics in the vehicle environment are suppressed by the first-order filters (with time constant a function of NDELAY). Unlike GENTRM6, the controls are not integrated.

(18) Transient delays in I.C. mode do not adversely influence subroutine TRIM, providing NDELAY is appropriately selected.

Communication with BASIC COMMON

In order to communicate with the COMMON arrays standardized for simulation models (BASIC), the following equivalences appear within subroutine TRIM. When the aircraft is not airborne (IHIT = 1), the calling sequence is ignored and communication is accomplished through the following cells:

Name	**Array**	**Definition (inputs when IHIT = 1)**
PBD	A(55)	Aircraft roll acceleration (rad/sec˝)
QBD	A(56)	Aircraft pitch acceleration (rad/sec˝)
VBD	A(414)	Right sideward acceleration (ft/sec˝)
WBD	A(415)	Downward acceleration (ft/sec˝)
XP	A(171)	X Position of pilot w/r/t C.G. (ft) (ICG = 0 only)
ZP	A(173)	Z Position of pilot w/r/t C.G. (ft) (ICG = 0 only)
XNG	A(187)	Nose wheel X w/r/t C.G. (ft)
YNG	A(188)	Nose wheel Y w/r/t C.G. (ft)
ZNG	A(189)	Nose wheel Z w/r/t C.G. (ft)
XRG	A(190)	Right wheel X w/r/t C.G. (ft)
ZRG	A(192)	Right wheel Z w/r/t C.G. (ft)
R2D	A(359)	Radians to degrees (deg/rad)

ICG	IA(64)	When set, input positions are w/r/t C.G. and not w/r/t pilot position coordinates.

Name	**Array**	**Definition (outputs when IHIT = 1)**
PHIIC	A(230)	Initial roll angle (deg)
THETIC	A(231)	Initial pitch angle (deg)
GAMVIC	A(233)	Initial flight path angle (deg) (value zeroed when IHIT=1)
HIC	A(241)	Initial height above runway (ft) (ICG dependent)

The above cells are ignored if the aircraft is airborne (IHIT = 0). This does not preclude their use, however, in the calling sequence. Switches and values that are of general use by subroutine TRIM are given by:

Name	**Array**	**Definition (inputs and outputs)**
IHIT	IA(9)	An input (to TRIM). Wheel or tail on ground when set.
IEVAL	IA(21)	An output. Trim evaluation discrete. Is set only once during each evaluation (every NDELAY counts), after each control has a chance to produce effect from cause (through the model, NDELAY cycles after a control change). IEVAL is always set by TRIM once every NDELAY cycles. This switch may be of use only to non-real-time models, possibly for printout control. Real-time models usually output controls and states continually.
ITPROG	IA(23)	An output. Trim is in progress when ITPROG is set. When this occurs the cab A/D's should be turned off.
IMANTR	IA(43)	An output. A flag that is set only if ITRMCM is manually reset. This flag is useful when aborting sequential trim processes, e.g., aircraft trim followed by power trim.
IREVAL	IA(44)	An input, and an output. When TRIM is entered (ITRMCM = 1) your value of IREVAL is saved for restoration upon proper exit from the routine. During the interim it is used as a counter from unity to its entrance value. IREVAL should probably be about 10, meaning that partials are evaluated every tenth time the controls are changed during the regression (as a total vector, not for individual partial evaluations). A required unity value for IREVAL undoubtedly means that the cyclic structure of the model's equations has a problem - because the partial derivatives after an incremental control change are significantly different from those prior to the change.
IPARTE	IA(45)	An output. Informs user which control is being perturbed during a partial evaluation sequence (order = calling sequence, sequential). Each time a control is changed (a secondary

		interval), NDELAY cycles later IEVAL is set to unity for one pass. This process occurs for each partial derivative evaluation, where the value of IPARTE cycles sequentially to a final value of NCONT. IPARTE is then reset. When IPARTE is zero, only primary evaluations are being performed. IPARTE may only be of interest to non-real-time models.
NDELAY	IA(46)	An input. This is the imposed delay count before "effect" is assumed to be established from "cause" (by observing the states). Typically, this value should be about 4, as required because of algebraic loops in simulation models. The model code may be in error if it must be appreciably larger. However, if dynamic processes occur in I.C. mode, such as in blade-element rotorcraft models (which emulate operate mode during I.C. mode), it may be required that this value be an order of magnitude higher. A minimum value of unity and a maximum value of 200 are imposed.
NMSGTR	IA(50)	Number of cycles delay between limit interference messages.
ITRMP	IA(103)	An output. The previous value of ITRMCM. Set and reset within TRIM (but not used within TRIM). (See the requirement, below, that TRIM be called when ITRMP = 1).
ITRMCM	IA(111)	Externally set by the user, this is also an output from TRIM when trim acceptance criteria are met. This is the trim mode discrete for TRIM. If this flag is reset by the user during trimming operations, IMANTR is set by TRIM.
ITBAD	IA(166)	An output. Control limit interference has occurred during trim when ITBAD is non-zero. The sign of ITBAD indicates whether an upper (+) or lower (-) limit has been hit (this feature may only be of interest to non-real-time models), and the value shows the offending control number. ITBAD is only determined during primary evaluations.
GAIN	A(255)	An input. Nominally 0.5, this value controls the convergence rate. If it is too large the controls are in danger of limit cycling, and if it is too small it may take forever to trim. If this quantity is ignored, TRIM takes care of it.

Common Requirements

In addition to the standard BASIC COMMON requirements,

```
COMMON/XFLOAT/A(500)/IFIXED/IA(250)
```

subroutine TRIM uses additional COMMON:

```
COMMON /FEXTRA/FEXT(20)
```

Contained in these cells (which are not available for redefinition) is the pseudo-state

vector created by subroutine TRIM:

Name	Definition
FEXT(I)	The first NSTATE values in this vector are observations of the state history, as used by TRIM. These values are the outputs of the first- order filters, with changing values each cycle. Because of this buffer, subroutine TRIM does not interfere with the actual states in the model.

Acceptance

Acceptance occurs if two vector conditions are met. These conditions are (1) that the absolute value of the difference between each state and its desired value DESVKT(I) is less than the acceptance criteria ACPVKT(I), and (2) that each control change (from primary evaluation to primary evaluation) be less than 0.1 percent of its range. The range of each control is defined by the difference TOPVKT(I) - BOTVKT(I).

In ground trim (IHIT = 1), acceptance occurs when PBD and QBD are less than .001 rad/sec^2 and when WBD and VBD are less than .01 ft/sec^2.

Manual "acceptance" occurs when ITRMCM is externally reset.

Subroutine TRIM should always be called in I.C. mode. Minimally, the following structure should be used:

```
IF(ITRMCM.NE.0.OR.ITRMP.NE.0) CALL TRIM(NCONT...
```

On subsequent trim attempts the calling sequence logic may be confused if the above call is not made when ITRMCM resets.

On the acceptance cycle, subroutine TRIM resets the values of IPARTE, ITPROG, and ITRMCM. (But IPARTE and ITPROG cannot be reset by TRIM if manual termination occurs and TRIM is not called as specified above). Also, IEVAL is set on this cycle if termination occurs from within TRIM. On the next pass (where ITRMCM has been reset during the previous cycle), the values for IEVAL and ITRMP are then reset. On any subsequent calls to TRIM, providing ITRMCM remains reset, an immediate return occurs. TRIM is then prepared for additional trimming operations.

Notes

The maximum and minimum control values are important inputs. Their differences, in particular, are used to determine the partial increment sizes. These are computed to be one-half of one percent of the range, i.e., 0.005*(TOPVKT(I) - BOTVKT(I)). Also, controls cannot exceed these limits regardless of whether this seems to be required during trim. When a control hits a limit it bounces off by 5 percent of the range, i.e., 0.05*(TOPVKT(I) - BOTVKT(I)).

Although zero errors are generally desired in the trim process, be reasonable. For

example, if the states {S1, S2, ...} are defined as {PBD, QBD, RBD, UBD, VBD, WBD}, (NSTATE=6), the values for ACPVKT(I) of {.001, .001, .001, .01, .01, .01} are recommended.

"Primary evaluations" are when the complete control vector is changed. Control perturbations, required in order to determine the partial derivatives, are "secondary evaluations".

Reevaluation of partials usually slows the trimming procedure; indeed, if IREVAL is set to unity the outputs of TRIM are approximately those of BQUIET.

When IEVAL = 1 and IPARTE $\neq$ 0, the controls have been used during the previous NDELAY cycles for evaluating partial derivatives with respect to a control perturbation. The value of IPARTE identifies the specific control.

When IEVAL = 1 and IPARTE = 0, the complete control vector has been changed, and this change has been propagating through the model for NDELAY cycles. Providing that NDELAY is sufficiently large, an observation of the states when IEVAL goes high and IPARTE = 0 is a good measure of state convergence. (In this case the states are examined after the complete control vector has a chance to operate on them through the model and then STRIKE or SMART). If observations of the statistically smoothed states are desired, they are available from the first NSTATE values of the FEXT(I) vector, which is declared in COMMON.

The utility of subroutine TRIM is not restricted to the flight simulation environment. It is a perfectly general regression analysis routine, providing only that the calling sequence is utilized (IHIT = 0 only).

Examples

In order to demonstrate subroutine TRIM, the BLACK HAWK model is used. In this model the states are those typically used in flight simulation. They consist of the vehicle axes linear and rotational accelerations. The controls are defined as X_B (longitudinal control), X_C (vertical control), X_A (roll control), X_P (yaw control), θ (pitch control), and either ϕ for the hover case or γ_H otherwise (lateral control). In each of three separate example flight conditions, the starting values (upon trim initiation) of all of the controls are identical.

In Figure 1 the 80-knot trim case is presented; in Figure 2 the hover case is presented; and in Figure 3 the 140-knot case is presented. These trim histories are all similar, each requiring less than 10 seconds to complete.

In these figures the entire trim process is shown. During the first few cycles, until about time T = 3 seconds, the partial derivatives are evaluated. Subsequently, in about an equal interval of time, the controls converge to those values required to null the states, as shown. The values GAIN = 0.5 and NDELAY = 40 were used.

The value of NDELAY = 40 is not required for trimming the Black Hawk model. This model will trim with NDELAY as small as 10. Also, it will trim faster. For example, Figure 4 is provided to show that for NDELAY = 15 the model trims twice as fast as it does in Figure 3, where NDELAY = 40. For NDELAY smaller than 10 the Black Hawk

model does not trim. This is caused by the slow rotor dynamics, in that nine cycles are not sufficient for the states to approach their final-value regions. Hence, the partial derivatives are improper for such a small value of NDELAY.

Figure 5 is presented to show the TRIM time requirements for various values of NDELAY. For the Black Hawk model, the value of NDELAY = 15 is optimal.

Check List

(1) The vehicle states should be fairly quiet before ITRMCM is set.

(2) The maximums and minimums should be selected with care. Their differences should not be unrealistically large, but just large enough to accommodate control deflections over the entire flight envelope.

(3) The basis for partial derivatives is determined from the initial control settings. Hence, if at all possible, the initial controls should be in the region of the anticipated final values.

(4) After the partials have been determined, if trim convergence seems to be either exceptionally slow, or oscillatory, consider increasing NDELAY rather than decreasing IREVAL. Unity IREVAL, for instance, causes a complete reevaluation of the partial derivative matrix every NDELAY cycles, and this will cost NCONT*NDELAY cycles, along with considerable overhead including matrix inversion.

(5) The value for GAIN need rarely be changed from its typical value of 0.5. The most common reason for trim failures is an inadequate value for NDELAY.

(6) Large values for NDELAY no longer impose the costly time penalties of the past. Hence, during initial checkout of a new model, it is a good idea to start with a large value for NDELAY, such as 40, and to later work the value down to a minimal region (for on-line operations).

(7) It is a good idea to store trim control configurations for later use. Then, despite possible flight regime variations, later trim processes will be very fast.

(8) Report trim problems (and solutions) to the author. All "sufficiently general improvements" in our trimming techniques should be included in subroutine TRIM.

Sample Call Structure

The following code is offered as an example of calling subroutine TRIM. In this example the partials are computed every third primary evaluation point by use of IREVAL.

```
C...Dimension trim arrays
      DIMENSION DESVKT(6),ACPVKT(6),BOTVKT(6),TOPVKT(6)
C
C...Control limits
      DATA DAPMIN,DAPMAX/-4.27,4.27/
      DATA DEPMIN,DEPMAX/-5.33,5.33/
      DATA DRPMIN,DRPMAX/-3.25,3.25/
      DATA DCPMIN,DCPMAX/0.0,10.65/
      DATA THETMIN,THETMAX/-10.0,10.0/
      DATA PHIMIN,PHIMAX/-10.0,10.0/
C
C...Desired values and acceptance tolerances
```

```
      DATA DESVKT/6*0.0/
      DATA ACPVKT/0.01,0.01,0.01,0.005,0.005,0.005/
C
C...In I.C. Mode, transfer control limits to arrays
C   (could have been done directly in a BLOCK DATA program)
      BOTVKT(1) = DEPMIN
      BOTVKT(2) = DCPMIN
      BOTVKT(3) = DAPMIN
      BOTVKT(4) = DRPMIN
      BOTVKT(5) = THETMIN
      BOTVKT(6) = PHIMIN
C
      TOPVKT(1) = DEPMAX
      TOPVKT(2) = DCPMAX
      TOPVKT(3) = DAPMAX
      TOPVKT(4) = DRPMAX
      TOPVKT(5) = THETMAX
      TOPVKT(6) = PHIMAX
C
C...Evaluate the partial derivatives every third primary
C   evaluation point:   (IREVAL is in A-COMMON, so this
C   should be a BLOCK DATA entry)
      IREVAL = 3
C
C...Turn off A/D's when trimming.
C...Read "NOADS" as "Number of A/D's" (don't know why...)
      IF(ITRMCM.EQ.1) NOADS = 0
C
C...Trim the aircraft states.  TRIM is called every cycle.
C
      CALL TRIM(6,DEPTRIM,DCPTRIM,DAPTRIM,DRPTRIM,
     1            THETIC,  PHIIC, C7    , C8    , C9, C10,
     2            BOTVKT, TOPVKT,
     3            UBD,VBD,WBD,PBD,QBD,RBD,S7,S8,S9,S10,
     4            DESVKT,ACPVKT)
C
C...If trimming termination, enable A/D's
C               (NOADS = 1 is sufficient on CDC)
      IF((ITRMCM.EQ.0).AND.(ITRMP.EQ.0)) NOADS = 1
C
C...End of example
```

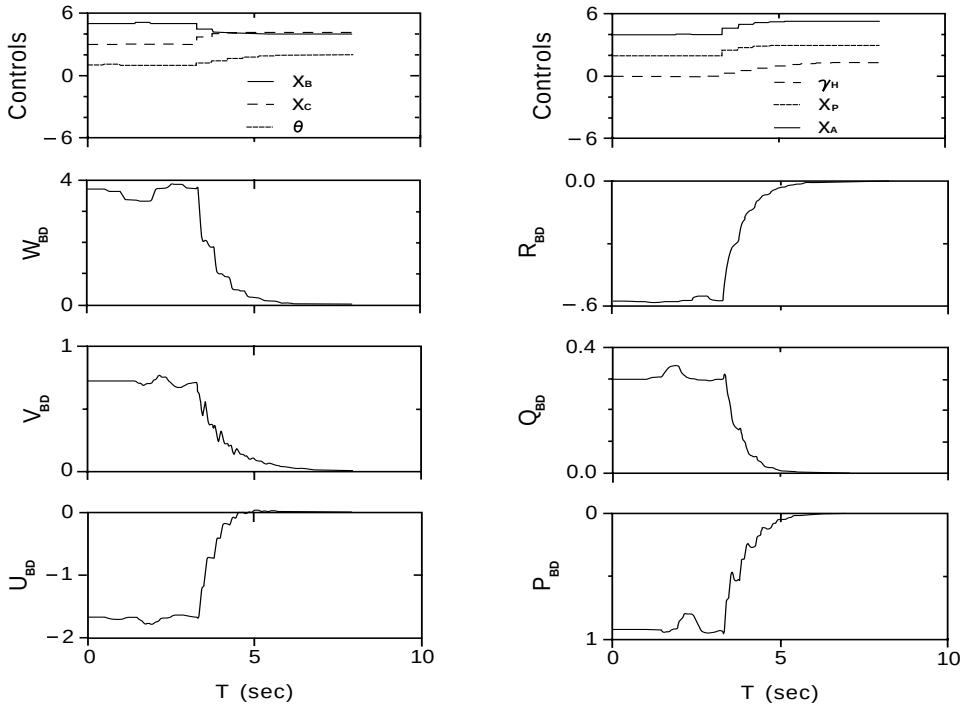

Figure 1 — 80 KNOT TRIM, NDELAY = 40

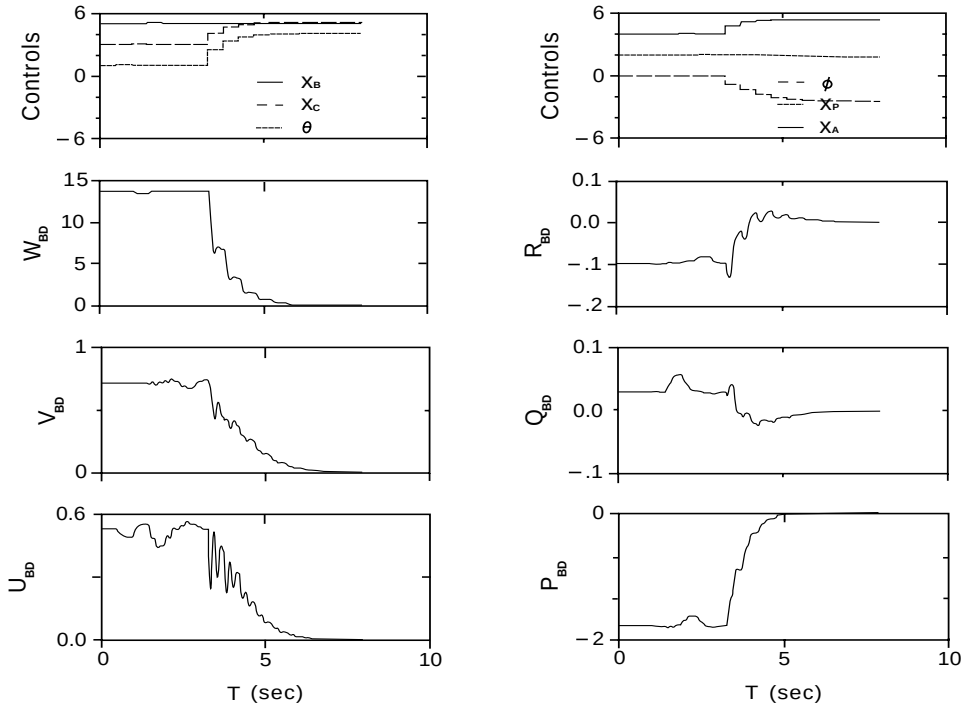

Figure 2 — HOVER TRIM, NDELAY = 40

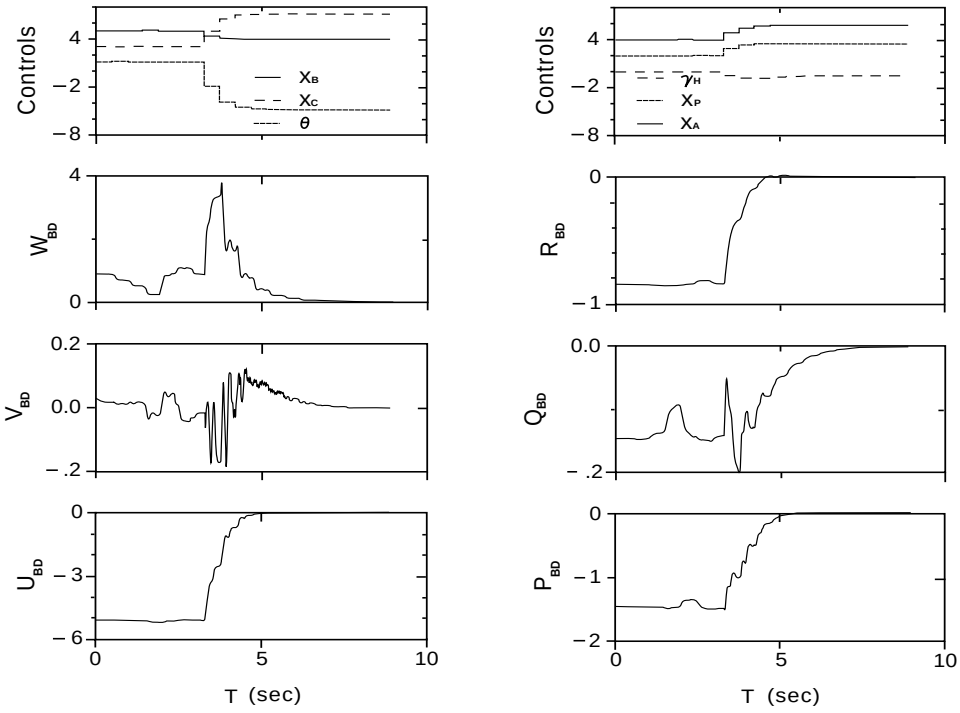

Figure 3 — 140 KNOT TRIM, NDELAY = 40

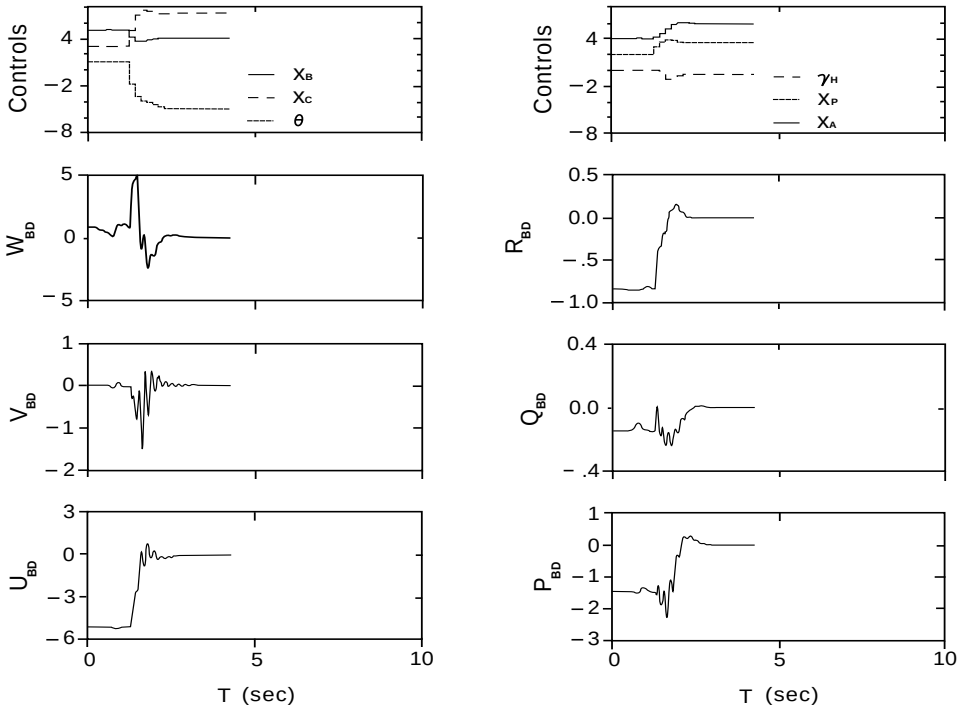

Figure 4 — 140 KNOT TRIM, NDELAY = 15

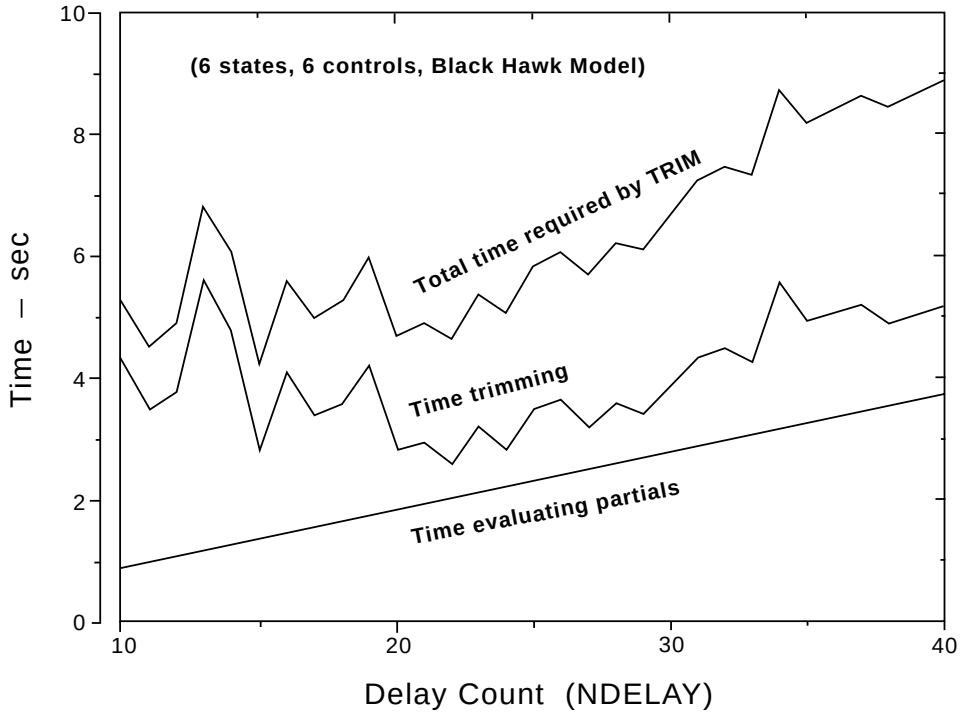

Figure 5 – TRIM Time Requirements

Subroutine TRIM

```
C*****  SOURCE FILENAME = TRIM                        12/12/94
C                                      SUBROUTINE PICK AT END
C                                      SUBROUTINE FILTIT AT END
C
C
C*************************************************************
C*****                                                   *****
C*****                 STRIKE SUBROUTINE                 *****
C*****                                                   *****
C*************************************************************
C
C
C23456789012345678901234567890123456789012345678901234567890123456789
C        1         2         3         4         5         6         7
C
C
C
      SUBROUTINE TRIM(NCONT,C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,
     1                BOTVKT,TOPVKT,
     2                NSTATE,S1,S2,S3,S4,S5,S6,S7,S8,S9,S10,
     3                DESVKT,ACPVKT)
C
C
C
C*********************************************************************
C                   SUBROUTINE ABSTRACT & HIERARCHY
C*********************************************************************
C
C   AUTHOR:  R. E. MCFARLAND  - NASA -
C
C          ------------------------------------
C          A COMPUTER PORTABLE TRIMMING ROUTINE
C          ------------------------------------
C
C     THIS PROGRAM REPLACES BQUIET AND GENTRM6.
C     IT IS COMPUTER PORTABLE.
C     IN COMPARISON, IT HAS MORE FEATURES:
C
C
C                       (1) PERMITS UP TO 10 CONTROLS.
C
C                       (2) PERMITS UP TO 10 STATES, AND YOU
C                           SELECT THEIR FINAL VALUES DESVKT(I)
C                           (WITHIN THE TOLERANCE VECTOR ACPVKT(I)).
C
C                       (3) THE NUMBER OF CONTROLS (NCONT) MAY BE
C                           GREATER THAN, EQUAL TO, OR LESS THAN
C                           THE NUMBER OF STATES (NSTATE).
C
C                       (4) YOU SELECT THE STATE ACCEPTANCE
C                           CRITERIA ACPVKT(I), IN THE UNITS OF
```

```
C                       YOUR OWN STATES.
C
C                    (5) THE PARTIAL DERIVATIVES ARE ONLY COMPUTED
C                        EVERY IREVAL PRIMARY CYCLES.
C
C                    (6) ALL REQUIRED DELAY LOGIC AND THE
C                        -TRIM COMPLETED- MESSAGE NOW INCLUDED
C                        WITHIN THIS ROUTINE.
C
C                    (7) ITRMCM IS AUTOMATICALLY RESET WHEN
C                        YOUR TRIM CRITERIA ARE MET, AND WHEN
C                        THE CONTROL VARIATIONS FROM ONE
C                        PRIMARY EVALUATION TO THE NEXT CHANGE
C                        LESS THAN 0.1 PERCENT (ACPCTL) OF
C                        THEIR RANGE (TOP(I) - BOT(I)).
C
C                        CONTROL QUIESCENCE AS WELL AS STATE
C                        NULLING REQUIRED FOR AUTOMATIC TRIM.
C                        (THE FIRST FEATURE IS SIMILAR TO GENTRM).
C
C                    (8) A MESSAGE APPEARS ON THE SCREEN WHENEVER
C                        A CONTROL (I) HITS YOUR BOTVKT(I) OR
C                        TOPVKT(I) LIMIT (IT WILL BOUNCE OFF).
C                          (SEE THE ABOVE MODIFICATION #1).
C
C                    (9) WHEN TRIM SENSES THAT THE AIRCRAFT
C                        IS NOT AIRBORNE (IHIT=1), THE CALLING
C                        SEQUENCE IS IGNORED AND A SPECIAL
C                        PROCESS TAKES OVER.  THIS PROCESS
C                        DETERMINES THE THREE QUANTITIES THETIC,
C                        HIC AND PHIIC, AS REQUIRED FOR ROTOR-
C                        CRAFT.  FOUR QUANTITIES ARE NULLED:
C                        PBD, QBD, WBD AND VBD.
C                        GAMVIC = 0 IS PROVIDED AS A SERVICE.
C                        IF YOUR AIRPORT IS ON A HILL, YOU WILL
C                        HAVE TO CHANGE THIS.
C
C                   (10) INVERSION PROCESS IS INTERNAL.
C
C                   (11) BOTH STATE AND CONTROL PROGRESS NOW
C                        AVAILABLE WHEN IEVAL HIGH.
C
C                   (12) TRIM USES A FIRST-ORDER LAG ON THE INPUT
C                        STATES WITH TIME CONSTANT = DT*NDELAY/4.
C                        THESE FILTERED STATES ARE INTERNAL.
C
C                        FOR THE BLACK HAWK MODEL, NDELAY = 10
C                        IS REQUIRED DUE TO ROTOR DYNAMICS IN
C                        I.C. MODE.
C
C                   (13) FEATURES IMMEDIATE TERMINATION WHEN
C                        EITHER (A) YOU TURN OFF ITRMCM, OR
C                        WHEN ACCEPTANCE IS AUTOMATIC (AND THIS
C                        PROGRAM TURNS OFF ITRMCM).   MANUAL
```

```
C                          RESET OF ITRMCM CAUSES IMANTR = 1
C
C                     (14) PROGRAM CALLS (ONLY):
C                          (A) FILTIT (BELOW)
C                          (B) PICK (BELOW)
C                          (C) BTYPE
C
C                     (15) TRIM IS COMPUTER PORTABLE.
C
C                     (16) TRIM IS THE FASTEST GUN IN AMES CITY...
C
C
C      THIS PROGRAM USES SUBROUTINE BTYPE FOR SCREEN MESSAGES.
C      BTYPE IS A REAL-TIME PROGRAM, BUT A FORTRAN COMPUTER PORTABLE
C      EQUIVALENT ROUTINE IS AVAILABLE IN THE STRIKE
C      ACCOUNT OF SIMDEV AND FSD VAX FOR NON-REAL-TIME OPERATIONS.
C      IT CONSISTS OF 2 LINES OF CODE THANKS TO JOHN BUNNELL (SYRE).
C
C ---------------------------------------------
C TRIM SHOULD BE CALLED FROM YOUR SETUP ROUTINE.
C ---------------------------------------------
C
C THE CALL TO SUBROUTINE STRIKE HAS BEEN TAKEN OUT IN THIS VERSION
C (AT THE END) HOWEVER, SUBROUTINE TRIM FUNCTIONS BETTER IF THE CALL
C IS PUT BACK INTO THIS CODE (AND YOU CONVERT TO THE STRIKE SYSTEM!).
C
C*********************************************************************
C
C                ***********************************
C                ***********************************
C
C               THIS IS A GENERALIZED AIRCRAFT TRIM
C               ROUTINE.  IT IS A BASIC ROUTINE FOR "NULLING"
C               (TO DESVKT(I)) UP TO 10 (NSTATE (M)) STATES,
C               BY MANIPULATING THE NCONT (N) CONTROLS (C'S).
C               (UP TO 10 CONTROLS ARE PERMITTED).
C
C               ITPROG WILL AUTOMATICALLY RESET IF ALL
C                  ABS(S(I)-DESVKT(I)).LT.ACPVKT(I)
C               AND ALL CONTROL CHANGES LESS THAN 0.1 (ACPCTL)
C               PERCENT OF THEIR RANGES,
C
C               OR, IN GROUND TRIM (IHIT=1),
C
C               PBD AND QBD LESS THAN .001 RAD/SEC2
C               WBD AND VBD LESS THAN .01 FT/SEC2.
C
C               ON-THE-GROUND TRIM IS AUTOMATIC IF
C               IHIT=1.  THE CALLING SEQUENCE, IN THIS
C               INSTANCE, IS IGNORED.
C
C               ITRMCM IS THE CONTROL SWITCH FOR THIS ROUTINE.
C               IT IS AUTOMATICALLY RESET IF ALL TRIM CRITERIA
C               ARE MET.  MANUAL TERMINATION (SETTING ITRMCM=0
```

```
C               YOURSELF) TERMINATES IMMEDIATELY WITH THE CONTROLS
C               RETURNED TO THE MOST RECENT PRIMARY EVALUATION
C               POINT.  HOWEVER, IF YOU WANT ITRMP TO BE RESET,
C               YOU MUST CALL TRIM ONE MORE TIME:
C
C             * * * * * * * * * * * * * * * * * * * * * * * * *
C             * IF(ITRMCM.GT.0.OR.ITRMP.GT.0) CALL TRIM(...  *
C             * * * * * * * * * * * * * * * * * * * * * * * * *
C
C HOWEVER, SINCE TRIM CALLS ARE ALWAYS IN YOUR SETUP ROUTINE
C (I.C. MODE), IT IS PREFERABLE TO ALWAYS CALL TRIM.  (NO CHECKING).
C
C
C ***************************************************************
C NOTE:  A SHELL IS NOT REQUIRED AROUND TRIM.  IT PERFORMS ALL OF
C        THE NDELAY LOGIC ITSELF AND PROVIDES MESSAGES.
C ***************************************************************
C
C  IF YOU WISH TO SEE (DISPLAY) THE PRIMARY EVALUATIONS,
C  PUT SOME SUCH CODE AS FOLLOWS IN YOUR SETUP (I.C.MODE) ROUTINE:
C
C         IF(ITRMCM.GT.0.OR.ITRMP.GT.0) CALL TRIM(NCONT, ...
C
C         IF(IEVAL.EQ.1) THEN
C                              FOR OBSERVING YOUR STATES,
C            WRITE(*,*) S1,S2,S3,...
C                              OR THE FILTERED VALUES,
C            WRITE(*,*) (FEXT(I),I=1,NSTATE)
C                              AND YOUR CONTROLS,
C         WRITE(*,*) C1,C2,C3,...
C         END IF
C
C         CALL (YOUR MODEL)
C         CALL STRIKE           (OR SMART, PROVIDING BSETUP CALLED)
C ***************************************************************
C
C          NOTE THAT THE  -TRIM COMPLETED-  MESSAGE IS
C          NOT IN YOUR CODE ANYMORE.  TRIM DOES IT, AS
C          WELL AS PROVIDE OTHER PERTINENT MESSAGES.
C
C
C
C*****************************************************************
C                   CREATION & MODIFICATION LOG
C*****************************************************************
C       DATE   INIT DOC#                   DESCRIPTION
C   ----------------------------------------------------------------
C
C     OCT 1987  R.E.MCFARLAND  - NASA -  BASED UPON BQUIET, OCT. 19,
1972,
C                   AND "TRIMMING AN AIRCRAFT MODEL FOR FLIGHT
SIMULATION",
C                   NASA TM 89466
C
```

```
C     08/17/89  REM  VERSION 1.0 (BETA VERSION) :
C                      CONFORMS TO THE ANSI FORTRAN STANDARD
C                      (HAS APPROPRIATE SAVES)
C                      SEE:  FSE PROGRAM SUMMARY DOCUMENT #1, "TRIM"
C
C     08/17/90  SCB  MODIFIED TO ELIMINATE COMPILATION WARNING ERRORS
C                    IN SUBROUTINE PICK
C
C     11/20/90  JOO  CHANGED IN THE FOLLOWING WAYS:
C                     1. ' LIMIT ERROR HIT ' MESSAGE TO APPEAR ONLY
C                          EVERY NMSGTR CYCLES, INFORMING USER OF ALL
THE
C                          RELEVANT CONTROLS ( FEATURE #8 ABOVE).
C                     2. CHANGED NAMES OF LOCAL VARIABLES TO AVOID
CONFLICT
C                          WITH BASIC NAMES.
C
C     02/11/91  SCB  A) MOVED TO STRIKE ACCT. ON THE CDC.
C                    B) REFORMATTED
C                    C) USED THE ANSI STD VARIABLE DIMENSION (*) IN
C                       TRIM AND FILTIT.
C
C     03/20/91  REM  VERSION 1.1
C                    CHANGED IREVAL LOGIC ALA USER REQUIREMENTS.  IT
C                    IS NOW A SKIP FACTOR.  UNITY MEANS THAT YOU WANT
C                    PARTIAL EVALUATIONS EVERY PRIMARY CYCLE.  TWO
C                    MEANS YOU WANT PARTIAL EVALUATIONS EVERY OTHER
C                    PARTIAL CYCLE, ETC.
C
C     08/16/91  SCB  REPLACE STOP STATEMENT WITH A CALL
C                    TO STOPCYC (WHICH STOPS CYCLING) AND
C                    SET ITRMCM = 0.
C
C     12/12/94  SCB  CONVERSION TO DEC FORTRAN 6.2
C
C
C
C*********************************************************************
C                  S I G N I F I C A N T   V A R I A B L E S
C*********************************************************************
C
C 3        12      20                                            63
C VARIABLE COMMON  ---------- D E F I N I T I O N ----------  UNITS
C NAME     ARRAY
C          LOCATION
C
C                  > > > >    I N P U T    < < < <
C                  -------------------------------
C
C     THE STATES ARE USUALLY DEFINED IN SIMULATION BY
C     THE FOLLOWING SIX VARIABLES, BUT YOU
C     MUST SPECIFY THEM IN THE CALLING SEQUENCE:
C
C PBD      A( 55)  AIRCRAFT ROLL ACCELERATION, B-FRAME        RAD/SEC2
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C QBD      A( 56)  AIRCRAFT PITCH ACCELERATION, B-FRAME       RAD/SEC2
C RBD      A( 57)  AIRCRAFT YAW ACCELERATION, B-FRAME         RAD/SEC2
C UBD      A(413)  FORWARD ACCELERATION, B-FRAME              FT/SEC2
C VBD      A(414)  RIGHT SIDEWARD ACCELERATION, B-FRAME       FT/SEC2
C WBD      A(415)  DOWNWARD ACCELERATION, B-FRAME             FT/SEC2
C
C ...THESE DATA VALUES ONLY NEEDED FOR GROUND TRIM..(IHIT = 1).......
C XP       A(171)  X POSITION OF PILOT W/R/T C.G.             FT
C ZP       A(173)  Z POSITION OF PILOT W/R/T C.G.             FT
C XNG      A(187)  NOSE WHEEL X W/R/T C.G.                    FT
C YNG      A(188)  NOSE WHEEL Y W/R/T C.G.                    FT
C ZNG      A(189)  NOSE WHEEL Z W/R/T C.G.                    FT
C XRG      A(190)  RIGHT WHEEL X W/R/T C.G.                   FT
C ZRG      A(192)  RIGHT WHEEL Z W/R/T C.G.                   FT
C R2D      A(359)  RADIANS TO DEGREES                         DEG/RAD
C ICG      IA(64)  WHEN SET, INPUT POS. ARE W/R/T C.G. AND
C                  NOT W/R/T PILOT POSITION COORDINATES.
C ..............................................................
C
C
C IHIT     IA(  9)  GROUND TOUCHED BY WHEEL OR TAIL
C
C NDELAY   IA( 46)  DELAY COUNT BEFORE ACQUISITION OF EFFECT FROM
C                   A PARTIAL CHANGE, OR A PRIMARY EVALUATION.
C                   TYPICALLY, THIS VALUE IS ABOUT 4, DUE TO
C                   ALGEBRAIC LOOPS IN A SIMULATION MODEL.  IF
C                   IT MUST BE APPRECIABLY LARGER, YOUR CODE MAY
C                   BE IN ERROR.  HOWEVER, IF DYNAMIC PROCESSES
C                   OCCUR IN I.C. MODE, SUCH AS IN BLADE-ELEMENT
C                   ROTORCRAFT MODELS, THIS VALUE MAY BE REQUIRED
C                   TO BE ON THE ORDER OF 20.
C
C ITRMCM   IA(111)  TRIM MODE DISCRETE FOR THIS ROUTINE.
C
C IMANTR   IA(43)   SEE OUTPUTS...
C
C NCONT             THE NUMBER OF CONTROLS YOU WANT TO USE FROM
C                   THE CALLING SEQUENCE LIST (WHICH IS PADDED
C                   OUT TO 10 VARIABLES).
C
C C1 - C10          CONTROL IDENTIFIERS FROM CALLING SEQUENCE.
C                   THESE QUANTITIES ARE OUTPUTS AS WELL AS INPUTS.
C                   HOPEFULLY, YOU DO NOT SELECT LINEARLY DEPENDENT
C                   CONTROLS.  IF ANY TWO CONTROLS PRODUCE PROPORTIONAL
C                   CHANGES IN THE STATE VECTOR, THIS PHENOMENON OF
C                   LINEAR DEPENDENCE WILL CAUSE HAVOC IN THE INVERSION
C                   PROCESS.
C
C BOTVKT(I)         A VECTOR CONTAINING YOUR CONTROL MINIMUM VALUES,
C                   IN THE ORDER OF THE TRIM CALLING SEQUENCE, AND
C                   OF LENGTH (DIMENSION) NCONT OR GREATER (UP TO 10)
C
C TOPVKT(I)         A VECTOR CONTAINING YOUR CONTROL MAXIMUM VALUES,
C                   IN THE ORDER OF THE TRIM CALLING SEQUENCE, AND
```

```
C                   OF LENGTH (DIMENSION) NCONT OR GREATER (UP TO 10)
C
C                   NOTE:
C
C                   THE MAXIMUMS AND MINIMUMS ARE IMPORTANT.
C                   THEIR DIFFERENCE, IN PARTICULAR, IS USED FOR
C                   DETERMINING YOUR PARTIAL INCREMENT SIZE, WHICH
C                   WILL BE ONE-HALF OF ONE PERCENT OF THE RANGE
C                   I.E.,  0.005*(TOPVKT(I) - BOTVKT(I)).
C
C                   ALSO, CONTROLS WILL NOT EXCEED THESE LIMITS
C                   REGARDLESS OF WHETHER THIS SEEMS TO BE
C                   REQUIRED DURING TRIM.  WHEN A CONTROL HITS A
C                   LIMIT IT BOUNCES OFF BY 5 PERCENT OF THE RANGE,
C                   I.E.,    0.05*(TOPVKT(I) - BOTVKT(I)).
C
C NSTATE            THE NUMBER OF STATES YOU WILL BE TRIMMING
C                   TO THE DESVKT(I) VALUES, FROM THE CALLING
C                   SEQUENCE LIST (WHICH IS PADDED OUT TO 10
C                   10 VARIABLES).
C
C S1 - S10          STATE IDENTIFIERS FROM CALLING SEQUENCE.
C                   THESE ARE INPUTS TO TRIM ONLY.  HOPEFULLY, WHEN
C                   TRIM CHANGES A CONTROL, CHANGES OCCUR IN YOUR
C                   MODEL IN AT LEAST ONE STATE, AND THAT THESE
C                   CHANGES BECOME RELATIVELY QUIESCENT IN NDELAY
C                   PASSES.
C
C DESVKT(I)         A VECTOR CONTAINING YOUR DESIRED FINAL STATE
C                   VALUES (USUALLY YOU WANT ZEROS), IN THE ORDER
C                   OF THE TRIM CALLING SEQUENCE, AND OF LENGTH
C                   (DIMENSION) NSTATE OR GREATER (UP TO 10).
C
C ACPVKT(I)         THE ACCEPTANCE (STATE TOLERANCE) VECTOR.
C                   A VECTOR CONTAINING THE POSITIVE ACCEPTANCE VALUES
C                   OF THE STATES MINUS THEIR DESIRED VALUES (ABSOLUTE
C                   VALUE) IN THE UNITS OF THE STATES, FOR
C                   AUTOMATIC TRIM TERMINATION.  DIMENSIONED
C                   NSTATE OR GREATER (UP TO 10).
C
C                   ALTHOUGH YOU DESIRE ZERO DIFFERENCES FOR TRIM,
C                   BE REASONABLE.  IF YOUR STATES ARE S1=PBD,
C                   S2=QBD,S3=RBD,S4=UBD,S5=VBD,S6=WBD,(NSTATE=6),
C                   FOR INSTANCE, THE VALUES FOR ACPVKT(I) OF
C                   .001,.001,.001,.01,.01,.01 ARE RECOMMENDED.
C
C                  A FIRST-ORDER FILTER IS USED IN ACQUIRING STATE
C                  DATA USED BY TRIM.  THE TIME CONSTANT IS
C                  DT*NDELAY/4, AND A TRIANGULAR DATA HOLD
C                  IS USED IN THE DISCRETE REALIZATION.
C
C
C     THE FUNCTION OF THE ACCEPTANCE VECTOR IS TO TURN OFF ITPROG
C     AND ITRMCM WHEN THE STATES ARE LESS THAN THESE VALUES, AND ALL
```

```
C     COMMUNICATION BOUNDARY PROBLEMS ARE SOLVED.
C  ------------------------------------------------------------
C
C               IF MORE CONTROLS THAN STATES ARE SELECTED, THE METHOD
C               OF LAGRANGE MULTIPLIERS IS USED.  IF LESS CONTROLS
C               THAN STATES ARE USED, THE LEAST SQUARES METHOD IS
C               USED (BUT WITHOUT WEIGHTS), SIMILAR TO  BQUIET.
C
C               UNLIKE BQUIET, THIS ROUTINE AIDS YOU IN THE
C               ACQUISITION OF THE STATES.
C               IT ACCUMULATES FILTERED VALUES FOR NDELAY COUNTS
C               BEFORE IT MAKES DECISIONS...
C
C   NDELAY  MINIMUM VALUE IS 1.  DURING NDELAY CYCLES
C           EACH STATE IS FILTERED AND ACCUMULATED
C           FOR EVENTUAL USE IN THE PARTIAL EVALUATIONS WHICH OCCUR
C           EVERY NDELAY CYCLES (SECONDARY EVALUATIONS).  THESE
C           PARTIALS ARE FOR EVENTUAL USE IN THE PRIMARY EVALUATION,
C           WHERE YOUR COMPLETE CONTROL VECTOR IS CHANGED BY TRIM.
C           AFTER THE PSEUDO-INVERSE IS OBTAINED, PARTIALS ARE NOT
C           RE-COMPUTED UNTIL IREVAL PRIMARY EVALUATIONS LATER.
C
C   IREVAL  IS ACQUIRED WHEN TRIM IS INITIALLY ENTERED, AND CHANGED
C           BY TRIM.  THE ORIGINAL VALUE IS RESTORED WHEN TRIM IS
C           PROPERLY TERMINATED.
C
C           A UNITY VALUE FOR IREVAL MEANS THAT THE TEDIOUS PROCESS
C           OF RE-COMPUTING THE PARTIAL DERIVATIVES AND CREATING THE
C           PSEUDO-INVERSE WILL OCCUR EVERY TIME A PRIMARY EVALUATION
C           IS MADE.  (A PRIMARY EVALUATION IS THE VECTOR CHANGE OF
C           ALL CONTROLS TO A NEW PRIMARY POINT, NDELAY*NSTATE CYCLES).
C           A VALUE OF TWO FOR IREVAL MEANS THAT THE SAME PARTIAL
C           DERIVATIVES MAY BE USED FOR TWO CONSECUTIVE PRIMARY
C           EVALUATIONS, AND THEN THE RE-EVALUATION OF PARTIALS
C           OCCURS.  A LARGE VALUE FOR IREVAL IS RECOMMENDED, LIKE
C           20.  THE BLACK HAWK MODEL HAS TRIMMED IN VERY FEW
C           CYCLES WITH A VALUE FOR IREVAL SO LARGE THAT RE-EVALUATION
C           OF PARTIALS NEVER OCCURRED.
C
C           THE STATE HISTORIES ARE FILTERED WITHIN TRIM, AND THE
C           OUTPUTS ARE USED FOR PARTIAL EVALUATIONS EACH NDELAY
C           COUNTS UNTIL THE PSEUDO-INVERSE MATRIX IS COMPUTED.
C
C   GAIN    NOMINALLY 0.5.  CONTROLS CONVERGENCE RATE.  IF IT IS TOO
C           LARGE THE CONTROLS WILL PROBABLY LIMIT CYCLE, AND IF IT
C           IS TOO SMALL IT WILL PROBABLY TAKE FOREVER TO TRIM.
C           IF YOU FORGET THIS, TRIM WILL TAKE CARE OF IT FOR YOU.
C
C   NMSGTR  NUMBER OF CYCLES BETWEEN ITBAD MESSAGES, AS DISPLAYED ON
C           THE SCREEN.  NOMINALLY SET IN BLOCK DATA BASIC TO 120,
C           BECAUSE THIS VALUE WAS DETERMINED TO BE LEAST ANNOYING TO
C           REAL-TIME OPERATIONS.
C
C  A PRIMARY CYCLE:
```

```
C  IF PARTIALS ARE BEING EVALUATED, A PRIMARY CYCLE CAN BE LARGE.
C  NDELAY CYCLES ARE REQUIRED BEFORE STATES ARE OBSERVED FROM EACH
C  CONTROL PERTURBATION.  HENCE, THIS TAKES NDELAY*NSTATE COMPUTER
C  CYCLES.  HOWEVER, IF PARTIALS ARE NOT BEING EVALUATED, A PRIMARY
C  CYCLE IS SIMPLY NDELAY CYCLES LONG.
C ****************************************************************
C
C
C                 > > > >    O U T P U T    < < < <
C                 --------------------------------
C
C .............ONLY FOR GROUND TRIM...........(IHIT=1).............
C PHIIC    A(230)  INITIAL ROLL ANGLE, L-FRAME                DEG
C THETIC   A(231)  INITIAL PITCH ANGLE, L-FRAME               DEG
C GAMVIC   A(233)  INITIAL FLIGHT PATH ANGLE ABOVE HORIZON    DEG
C                  (VALUE ZEROED HEREIN WHEN IHIT=1)
C HIC      A(241)  INITIAL HEIGHT ABOVE RUNWAY                FT
C ..............................................................
C
C IEVAL    IA(21)  TRIM EVALUATION DISCRETE.  IS SET ONLY ONCE
C                  PER EACH EVALUATION (EVERY NDELAY COUNTS).
C
C                  (A PRIMARY EVALUATION IS WHEN THE COMPLETE
C                   CONTROL VECTOR IS CHANGED.  CONTROL PERTURBATIONS,
C                   REQUIRED IN ORDER TO DETERMINE PARTIAL
C                   DERIVATIVES ONLY, ARE "SECONDARY EVALUATIONS").
C
C                   A PRIMARY EVALUATION HAS OCCURRED FOR NDELAY
C                   CYCLES WHEN IEVAL = 1 AND IPARTE = 0.
C
C                  ONLY PRIMARY EVALUATIONS OCCUR AFTER ALL OF THE
C                  CONTROLS (IPARTE VALUES) HAVE BEEN EXHAUSTED.
C
C                  WHEN IEVAL = 1 YOUR CONTROLS HAVE BEEN USED
C                  DURING THE LAST NDELAY CYCLES FOR THE EVALUATION
C                  OF PARTIAL DERIVATIVES.  IF IPARTE = 0, THEY ARE
C                  THE RESULT OF A COMPLETE CHANGE IN THE CONTROL
C                  VECTOR (I.E. A PRIMARY EVALUATION), AND THE
C                  INFLUENCE ON YOUR STATES HAS BEEN GIVEN NDELAY
C                  CYCLES TO PROPAGATE THROUGH YOUR MODEL.  PROVIDING
C                  THAT NDELAY IS SUFFICIENTLY LARGE ENOUGH, YOUR
C                  OBSERVATION OF THE STATES WHEN IEVAL GOES HIGH
C                  AND IPARTE = 0 IS A GOOD MEASURE OF CONVERGENCE.
C
C                  IN THIS CASE YOU ARE EXAMINING THE STATES AFTER
C                  THE COMPLETE CONTROL VECTOR HAS A CHANCE TO
C                  OPERATE ON THEM (THROUGH YOUR MODEL AND THEN
C                  STRIKE OR SMART).
C                  THIS OBSERVATION (OF YOUR STATES)
C                  IS NOT OF THE STATISTICALLY SMOOTHED STATES
C                  CREATED AND USED WITHIN TRIM, BUT IS ONLY ONE
C                  OBSERVATION OF YOUR ACTUAL STATE HISTORY.
C
C                  IF YOU WANT TO MONITOR THE STATISTICALLY SMOOTHED
```

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C                  STATES, THEY ARE AVAILABLE IN THE FIRST NSTATE
C                  VALUES OF FEXT(I), WHICH IS DECLARED AS COMMON.
C
C                  IEVAL GOES HIGH AFTER NDELAY COUNTS DURING EACH
C                  PARTIAL EVALUATION.  THIS GIVES THE CONTROL
C                  VECTOR TIME TO INFLUENCE THE STATES.
C
C                  IEVAL AND ITRMP WILL REMAIN HIGH AFTER ITRMCM = 0
C                  UNLESS YOU CALL TRIM AGAIN.
C
C IPARTE   IA( 45) INFORMS USER WHICH CONTROL IS BEING PERTURBED
C                  (ORDER = CALLING SEQUENCE).  WHEN IPARTE = 0
C                  THE PRIMARY EVALUATION HAS BEEN PERFORMED, AND
C                  NDELAY COUNTS HAVE PASSED TO PROPAGATE INFLUENCE
C                  THROUGH YOUR MODEL.  HENCE, WHEN IPARTE RESETS,
C                  NDELAY COUNTS LATER IEVAL IS SET FOR ONE CYCLE.
C
C                  EACH TIME IPARTE CHANGES, NDELAY CYCLES LATER
C                  IEVAL WILL BE SET TO UNITY FOR ONE PASS.
C
C                  THIS PROCESS OCCURS FOR EACH PARTIAL EVALUATION.
C                  IPARTE REMAINS CONSTANT (IPARTE = 1,2,...NCONT) FOR
C                  NDELAY COUNTS DURING EACH CONSECUTIVE PARTIAL
C                  EVALUATION.
C
C                  WHEN ALL PARTIALS HAVE BEEN COMPUTED, IPARTE WILL
C                  BECOME ZERO UNTIL IREVAL PRIMARY EVALUATIONS ARE
C                  MADE.  PARTIALS ARE THEN RECOMPUTED.
C
C IMANTR   IA(43)  THIS FLAG IS SET ONLY WHEN ITRMCM IS MANUALLY RESET.
C                  THIS IS USEFUL WHEN SEQUENTIAL TRIM PROCESSES ARE
C                  ABORTED BY THE USER (E.G., AIRCRAFT TRIM FOLLOWED
C                  BY POWER TRIM).
C
C IREVAL   IA(44)  IS ACQUIRED WHEN TRIM INITIALLY ENTERED, AND USED
C                  AS A COUNTER HEREIN.  IT IS RESTORED WHEN TRIM
C                  IS TERMINATED.  IREVAL SHOULD BE ABOUT 10 FOR A
C                  TYPICAL ROTORCRAFT SIMULATION.
C
C ITPROG   IA(23)  TRIM IN PROGRESS WHEN ITPROG=1.  WHEN THIS OCCURS
C                  YOU SHOULD TURN OFF YOUR A/D'S.
C
C ITRMP   IA(103)  THE PREVIOUS VALUE OF ITRMCM.
C                  ITRMP IS SET IN THIS ROUTINE WHEN ITRMCM IS SET.
C                  IT IS RESET IN THIS ROUTINE IF YOU CALL TRIM AFTER
C                  ITRMCM IS RESET.  THIS FLAG IS NOT USED BY TRIM,
C                  BUT YOU WILL CONFUSE YOUR CALLING LOGIC IF YOU DO
C                  NOT EITHER (A) CALL TRIM ALL THE TIME IN I.C. MODE,
C                  OR (B) CALL TRIM WHEN EITHER ITRMP OR ITRMCM = 1,
C                  I.E.,
C
C         IF(ITRMCM.GT.0.OR.ITRMP.GT.0) CALL TRIM(NCONT, ...
C
C ITBAD    IA(166) CONTROL LIMIT INTERFERENCE DURING TRIM WHEN
```

```
C                  ITBAD.NE.0 NOT NECESSARILY CRITICAL, BECAUSE
C                  THE CONTROLS MAY CONVERGE EVENTUALLY.  THE
C                  SIGN OF THIS QUANTITY (IF ONLY ONE LIMIT HIT)
C                  INDICATES WHETHER AN UPPER (+) OR LOWER
C                  (-) LIMIT HAS BEEN REACHED.  ITS VALUE INDICATES
C                  THE SPECIFIC CONTROL (IN THE CALLING SEQUENCE ORDER).
C                  SEE NMSGTR, ABOVE, FOR SCREEN OUTPUT FREQUENCY.
C
C -------------------------------------------------------------
C     IN COMPARISON WITH THE SIMILAR (SUBSET) PROGRAM CALLED BQUIET,
C     THE STATE AND CONTROL VECTORS STATE(I) AND CONT(I) HAVE BEEN
C     ELIMINATED.  THESE WERE VECTORS CONSTRAINED TO 6 ELEMENTS WITHIN
C     BASIC COMMON.
C -------------------------------------------------------------
C
C
C
C*********************************************************************
C                  C O M M O N S
C*********************************************************************
C
      COMMON/XFLOAT/A(500)/IFIXED/IA(250)
C
C*****  MCFARLAND'S SPECIAL COMMON ARRAY.  DO NOT USE FOR ANY
C                                     ADDITIONAL PURPOSES.
      COMMON /FEXTRA/FEXT(20)
C
C
C
C
C*********************************************************************
C                  D E C L A R A T I O N S
C*********************************************************************
C
C*****  YOURS, DIMENSIONED NCONT OR GREATER (TO 10)
C
      DIMENSION BOTVKT(*),TOPVKT(*)
C
C*****  YOURS, DIMENSIONED NSTATE OR GREATER (TO 10)
C
      DIMENSION DESVKT(*),ACPVKT(*)
C
C*****  MINE, UPPER LIMIT OF 10 SHOULD BE OBVIOUS...
C
      DIMENSION H(10,10),DQC(10),DQCI(10),QC(10),Z(100),Q(10,10)
      DIMENSION DX(10),CMIN(10),CK(10),QD(10),E(10,10)
      DIMENSION YZ(10),BB(10),IN(10)
      DIMENSION S(10),TEMTR(10),QCOLD(10)
C
C
C*****  MESSAGE VARIABLES.
C
C
      DIMENSION ITBADL(10)
```

```
      DIMENSION ITBADU(10)
C
C
      CHARACTER*40 AMESG
      CHARACTER*40 AMESGL(10)
      CHARACTER*40 AMESGU(10)
      CHARACTER*2 NUM(10)
C
C
      SAVE IHITP,IPRONE,ITFLAG,KTRMP,M,N,NK,CK,CMIN,DQC,E,H,
     1     QC,QCOLD,QD,S,TEMTR,YZ
C
C
C
C
C*********************************************************************
C                 E Q U I V A L E N C E S
C*********************************************************************
C
      EQUIVALENCE (A( 55), PBD)
      EQUIVALENCE (A( 56), QBD)
      EQUIVALENCE (A( 57), RBD)
      EQUIVALENCE (A(168), DT2)
C
      EQUIVALENCE (A(171), XP)
      EQUIVALENCE (A(173), ZP)
      EQUIVALENCE (A(187), XNG)
      EQUIVALENCE (A(189), ZNG)
      EQUIVALENCE (A(190), XRG)
      EQUIVALENCE (A(192), ZRG)
C
      EQUIVALENCE (A(230), PHIIC)
      EQUIVALENCE (A(231), THETIC)
      EQUIVALENCE (A(233), GAMVIC)
      EQUIVALENCE (A(241), HIC)
      EQUIVALENCE (A(255), GAIN)
      EQUIVALENCE (A(359), R2D)
      EQUIVALENCE (A(413), UBD), (A(414), VBD), (A(415), WBD)
C
      EQUIVALENCE (IA(  9), IHIT   )
      EQUIVALENCE (IA( 21), IEVAL  ), (IA( 23), ITPROG )
      EQUIVALENCE (IA( 43), IMANTR )
      EQUIVALENCE (IA( 44), IREVAL ), (IA( 45), IPARTE )
      EQUIVALENCE (IA( 46), NDELAY )
      EQUIVALENCE (IA( 50), NMSGTR )
      EQUIVALENCE (IA( 64), ICG    ), (IA(103), ITRMP  )
      EQUIVALENCE (IA(111), ITRMCM ), (IA(166), ITBAD  )
C
C
      EQUIVALENCE (Q(1,1),Z(1))
C
C
C
C
```

```
C*****************************************************************
C                  D A T A    I N I T I A L I Z A T I O N
C*****************************************************************
C
C                ***************************************
C                *  (NO COMMON IS INITIALIZED IN TRIM)    *
C                ***************************************
C
C     CONTROL INCREMENT ONE HALF OF ONE PERCENT (UP TO 10 CONTS)
C
      DATA DQCI  /  0.005, 0.005, 0.005, 0.005, 0.005,
     1              0.005, 0.005, 0.005, 0.005, 0.005  /
C
C*****  (NOT USED IN GROUND TRIM; IT USES ONE TENTH OF ONE PERCENT)
C
C
C*****  XIJK = 0.2 MEANS THAT CONTROLS MAY NEVER CHANGE BY MORE THAN
C*****         TWENTY PERCENT OF THEIR RANGE IN A PRIMARY EVALUATION.
C
      DATA XIJK   /   0.20  /
      DATA IHITP  /    0    /
      DATA KTRMP  /    0    /
C
C*****  MAX = 10 REQUIRED BECAUSE OF MAXIMUM DIMENSIONS ALLOWED.
C
      DATA NK     /    0    /
      DATA MAX    /   10    /
      DATA ITFLAG /    0    /
C
C*****  CONTROL VARIATIONS WITHIN 0.1 PERCENT FOR ACCEPTABLE TRIM
C
      DATA ACPCTL /   0.001 /
C
C*****  NEEDED FOR MESSAGES.
C
      DATA NUM   / ' 1', ' 2', ' 3', ' 4', ' 5',
     1             ' 6', ' 7', ' 8', ' 9', '10' /
C
C*****  INITIALIZE FOR DEC FORTRAN 6.2
C
      DATA KREVAL /    0    /
C
C
C
C
C*****************************************************************
C                  E X E C U T A B L E    C O D E
C*****************************************************************
C
C*****  RESET MESSAGE COUNTER.
C
      IF((ITRMCM.GT.0) .AND. (ITRMP.EQ.0) )THEN
        KMESS = NMSGTR
      END IF
```

```
C
C
      IF(ITRMCM .GT. 0) GO TO 430
C
      IF(ITRMP .GT. 0) THEN
        ITRMP = 0
        IEVAL = 0
      END IF
C
C*****  IF EITHER MANUAL OR AUTOMATIC TRIM OCCURRED BEFORE, QUIT.
      IF(KTRMP.EQ.0) RETURN
C
C*****  MANUAL TERMINATION OF TRIM HERE (KTRMP STILL SET).
C*****  EXIT AND RETURN LAST PRIMARY CONTROL VECTOR.
      CALL BTYPE(37,'TRIM:  AS REQUESTED, TRIM TERMINATED.')
      IMANTR = 1
C
C*****  PUT QD BACK INTO THE CONTROL VARIABLES BECAUSE TRIM MAY BE
C*****  IN THE MIDDLE OF A CONTROL PERTURBATION (N = NSTATE).
      IF(IHIT.EQ.1) GO TO 410
        GO TO (390,380,370,360,350,340,330,320,310,300),N
  300   C10 = QD(10)
  310   C9  = QD(9)
  320   C8  = QD(8)
  330   C7  = QD(7)
  340   C6  = QD(6)
  350   C5  = QD(5)
  360   C4  = QD(4)
  370   C3  = QD(3)
  380   C2  = QD(2)
  390   C1  = QD(1)
        GO TO 420
C
  410 THETIC = QD(1)
      HIC    = QD(2)
      PHIIC  = QD(3)
C
C
C*****  EXIT FROM BELOW IF EITHER MANUAL OR AUTOMATIC TERMINATION.
C*****  IF YOU WANT IEVAL AND ITRMP RESET,
C*****  THEN CALL TRIM AGAIN AFTER ITRMCM=0.
C*****  THIS IS A WAY TO TRIGGER PRINTOUTS OF PRIMARY EVALUATIONS.
C
  420 IPARTE = 0
      NK     = 0
C
C*****  NOTE ITPROG RESET HERE, ONE PASS BEFORE IEVAL AND ITRMP RESET.
      ITPROG = 0
      ITFLAG = 0
      ITRMCM = 0
C
C*****  PROTECT (INTERNALLY) FROM ENTERING HERE AGAIN (ABOVE CHECK).
      KTRMP  = 0
C
```

```
C*****  RESTORE USER'S IREVAL WHEN LEAVING.
      IREVAL = KREVAL
      RETURN
C
C*****  FOR AUTOMATIC TRIM ACCEPTANCE (ELSEWHERE), CONSIDER:
C*****   IN YOUR DRIVING PROGRAM, AFTER (ITRMCM = 1), THE CONDITION
C*****   (ITRMCM.EQ.0)  IDENTIFIES THE PASS WHEN TRIM
C*****   IS COMPUTED TO BE SATISFACTORY IN TRIM.  YOU GET THE MESSAGE
C*****   "TRIM COMPLETED"  DURING THIS PASS, AND THE VALUES FOR
C*****   ITRMCM AND ITPROG ARE SET TO ZERO.  ON THE NEXT PASS,
C*****   IF YOU CALL TRIM AGAIN, ITRMP AND IEVAL WILL ALSO BE RESET.
C
C*****  SUBSEQUENT PASSES, IF ITRMCM REMAINS IN THE RESET CONDITION,
C*****  WILL PRODUCE AN IMMEDIATE RETURN FROM TRIM.
C
C*****  IS THIS YOUR FIRST VISIT?
  430 IF(KTRMP.EQ.0) GO TO 440
C
C*****  NO, BEEN IN TRIM (CONTIGUOUSLY) BEFORE:
        NK = NK + 1
        IEVAL = 0
        IF(IPARTE.EQ.0.AND.NK.EQ.(NDELAY-1)) IEVAL = 1
C
C*****  OBSERVE OUTPUTS FROM THIS ROUTINE WHEN IEVAL = 1.  THIS WILL
C*****  OCCUR FOR ONCE EACH PARTIAL EVALUATION.  IF IPARTE IS ALSO ZERO,
C*****  THIS IS A PRIMARY EVALUATION POINT.
C*****  AFTER THE PARTIALS HAVE BEEN ACQUIRED, IPARTE STAYS ZERO UNTIL
C*****  IREVAL INCREMENTS TO ITS ORIGINAL VALUE (WHEN TRIM ENTERED).
C
C*****  EVALUATION OF STATES:
C*****  THE SINGLE EVALUATION OF EACH FILTERED STATE IS MADE AT THE
C*****  END POINT WHEN NK.EQ.NDELAY
C
C*****  RESET ACCUMULATORS WHEN NK = 1
C
C*****  SUMMATIONS
        IF(IHIT.EQ.1) THEN
C
C*****  NOTE, DESIRED VALUES IN THIS INSTANCE ARE ZERO.  (NO BIASES)
          TEMTR(1) = PBD
          TEMTR(2) = QBD
          TEMTR(3) = WBD
          TEMTR(4) = VBD
        ELSE
C
C*****  HOWEVER, WHEN CALLING SEQUENCE USED, BIASES TAKEN OUT HERE.
          CALL PICK(M,S1,S2,S3,S4,S5,S6,S7,S8,S9,S10,TEMTR,DESVKT)
C
C*****  DESIRED TEMTR(I) (AND HENCE S(I)) ARE ALWAYS ZERO!
        END IF
C
        CALL FILTIT(M,ITFLAG,DESVKT,TEMTR,S)
C
        IF(NK.LT.NDELAY) RETURN
```

```
C
C*****  WE HAVE OUR NEW ACCUMULATED STATES WHEN NK = NDELAY.
C
      NK = 0
C
C*****  WE MIGHT, FOR INSTANCE, HIT THE GROUND DURING AIRBORNE TRIM,
C*****  OR EVEN LIFT OFF DURING GROUND TRIM...
      IF(IHIT .EQ. IHITP) GO TO 500
C
C*****  IN WHICH CASE WE WILL FALL THROUGH TO HERE...
      CALL BTYPE(31,'TRIM:  GROUND-AIR TRANSITION.  ')
C
C*****  BEGIN ONE-SHOT INITIALIZATION ******************
C
C*****  THIS IS A NEW TRIM ATTEMPT.
C*****  LET'S INITIALIZE THIS SUCKER...
  440 NK = 0
      IMANTR = 0
      ITFLAG = 0
C
C*****  ONE POSSIBLE PRINTOUT THAT STATES O.K., WAITING FOR CONTROLS...
      IPRONE = 1
C
C*****  IN CASE YOU FORGOT GAIN...
      IF(GAIN.LT.0.01) GAIN = 0.5
      IF(GAIN.GT.1.0)  GAIN = 0.5
C
      IF(NDELAY.LT.1) THEN
        NDELAY = 1
        CALL BTYPE(37,'TRIM:  NDELAY TOO SMALL.  SETTING = 1')
      END IF
C
      IF(NDELAY.GT.200) THEN
        CALL BTYPE(31,'TRIM:  NDELAY.GT.200 TOO LARGE.')
        CALL BTYPE(27,'TRIM:  SETTING NDELAY = 40.')
        NDELAY = 40
      END IF
C
C*****  INFORM USER THAT TRIMMING IS IN PROGRESS
      ITPROG = 1
      ITRMP = 1
C*****  AND WE MAKE DECISIONS BASED UPON THESE VALUES
      KTRMP = 1
      IEVAL = 0
C
C*****  DETERMINE REQUESTED PARTIAL EVALUATION SKIP FACTOR (ORIGINAL
IREVAL)
      KREVAL = IREVAL
      IF(KREVAL.LE.0) KREVAL = 20
C*****  SETUP FOR IMMEDIATE EVALUATIONS
      IREVAL = KREVAL
C
C*****  GROUND TRIM IS DETERMINED BY IHIT=1 (INPUT).
C*****  MINIMUMS AND MAXIMUMS ARE COMPUTED FROM GEOMETRY IN THIS
```

```
C*****  CASE AND CONTROLS ARE FORCED TO BE THETIC, HIC AND PHIIC.
C*****  CONTROL LIST IGNORED IN THIS CASE.
C
      IF(IHIT.EQ.0) GO TO 470
        CALL BTYPE(31,'TRIM:  GROUND TRIM INITIATED.  ')
        GAMVIC = 0.
        PHIIC = 0.
        IHITP = 1
C
C*****  WE DO NOT CHANGE YOUR CALLING SEQUENCE!
C*****  THE THREE CONTROLS ARE THETIC, HIC AND PHIIC
        N = 3
C*****  THE FOUR STATES ARE PBD, QBD, WBD AND VBD
        M = 4
C
C*****  YOU MAY NOTE THAT SOME QUANTITIES COMPUTED HERE ARE NOT IN
C*****  COMMON.  IN FACT, THIS IS ONE REASON WHY THE STRIKE SYSTEM IS
C*****  SUPERIOR TO THE SMART SYSTEM.  SUBROUTINE TRIM CANNOT
C*****  TAKE RESPONSIBILITY FOR CHANGING ALL OF THE MANY VARIABLES
C*****  THAT CHANGE WHEN ONE OF THESE CONTROLS ARE CHANGED (I.E.,
C*****  THETIC SHOULD CHANGE ELEMENTS OF LOCAL-TO-BODY TRANSFER
C*****  FUNCTION MATRIX).  IF THE CALL TO STRIKE HEREIN (AT END) IS
C*****  PUT BACK INTO THE CODE, THEN WHENEVER ONE OF THESE
C*****  BASIC QUANTITIES IS CHANGED BY TRIM ITS INFLUENCE
C*****  WOULD THEN CORRECTLY PROPAGATE THROUGHOUT THE MODEL.
C*****  HOWEVER,
C*****  IT IS NOT A GOOD IDEA TO CHANGE JUST SOME OF THESE VALUES...
C*****  FOR THE ABOVE REASONS DO NOT PUT THETR, STHT, CTHT, ETC.
C*****  IN COMMON STATEMENTS IN THIS SUBROUTINE!
C
C*****  ANYBODY WISHING TO CONVERT A SIMULATION TO THE STRIKE SYSTEM,
C*****  I WILL GIVE THEM 10 MINUTES OF MY TIME.  THAT'S ALL THE TIME
C*****  IT SHOULD TAKE.  R.E.M.
C
        IF(R2D.LT.57.0) THEN
          CALL BTYPE(34,'TRIM:  YOU DID NOT INITIALIZE R2D.')
          CALL BTYPE(39,'       SERVICE PROVIDED FOR YOU, DUMMY.')
          R2D = 57.2957795
        END IF
C
      ZX = SQRT((ZNG-ZRG)**2+(XNG-XRG)**2)
      THETRX = ATAN2((ZNG-ZRG),ZX)
      THETIC = R2D*THETRX
      STHTTR = SIN(THETRX)
      CTHTTR = COS(THETRX)
C
C*****  WHEEL GEOMETRY.
C*****  USING LOGIC FROM STRIKE, DETERMINE I.C. TYPE...
C
      IF(ICG.EQ.1) GO TO 450
C
C*****  I.C.'S ARE WITH RESPECT TO PILOT LOCATION.
        HICMAX = (ZRG-ZP)*CTHTTR+(XP-XRG)*STHTTR
        CMIN(2) = HICMAX-0.5*ZNG
```

```
        GO TO 460
C
C*****  I.C.'S ARE WITH RESPECT TO C.G.
  450 HICMAX = ZRG*CTHTTR-XRG*STHTTR
      CMIN(2) = HICMAX-0.5*ZRG
C
  460 PHIMAX = 3.0
      CMIN(3) = - 3.0
      CK(3) = PHIMAX - CMIN(3)
      CK(2) = HICMAX-CMIN(2)
      HIC = HICMAX-0.1*ZRG
      THTMAX = ATAN2(ZNG,SQRT(ZNG**2+(XNG-XRG)**2))*R2D
      CMIN(1) = ATAN2(-ZRG,ZX)*R2D
      CK(1) = THTMAX-CMIN(1)
C
C*****  NORMALIZED PARTIAL EVALUATION INCREMENTS WHEN ON GROUND (-.1
PCENT)
C*****  (INTO GROUND, NOT ABOVE!)
      DQC(1) = -.001
      DQC(2) = -.001
      DQC(3) = -.001
C
      QC(1) = (THETIC-CMIN(1))/CK(1)
      QC(2) = (HIC-CMIN(2))/CK(2)
      QC(3) = (PHIIC-CMIN(3))/CK(3)
      QCOLD(1) = QC(1)
      QCOLD(2) = QC(2)
      QCOLD(3) = QC(3)
        TEMTR(1) = PBD
        TEMTR(2) = QBD
        TEMTR(3) = WBD
        TEMTR(4) = VBD
        CALL FILTIT(M,ITFLAG,DESVKT,TEMTR,S)
C*****  BEGIN ESTABLISHMENT OF BASIS
        IPARTE = 0
        RETURN
C
C*****  AIRBORNE TRIM (CALLING SEQUENCE USED)
C
  470 N = NCONT
      M = NSTATE
      IHITP = 0
C
C*****  SERIOUS ERRORS.
        IF(N.LT.1) THEN
          CALL BTYPE(24,'TRIM:  TOO FEW CONTROLS.')
          ITRMCM = 0
          CALL STOPCYC
        END IF
C
        IF(M.LT.1) THEN
          CALL BTYPE(22,'TRIM:  TOO FEW STATES.')
          ITRMCM = 0
          CALL STOPCYC
```

```
        END IF
C
        IF(N.GT.10) THEN
          CALL BTYPE(25,'TRIM:  TOO MANY CONTROLS.')
          ITRMCM = 0
          CALL STOPCYC
        END IF
C
        IF(M.GT.10) THEN
          CALL BTYPE(23,'TRIM:  TOO MANY STATES.')
          ITRMCM = 0
          CALL STOPCYC
        END IF
C
C*****  NO ERRORS - PRINT TRIM STARTED MESSAGES
      CALL BTYPE(22,'TRIM:  TRIM INITIATED ')
C               1234567   89       0123456789   01       234567890
      AMESG = 'TRIM: '//NUM(N)//' CONTROLS,'//NUM(M)//' STATES.  '
      CALL BTYPE(30,AMESG)
C
C
C*****  PARTIAL EVALUATION INCREMENTS WHEN AIRBORNE (0.5 PERCENT)
      DO 480 I=1,N
        DQC(I) = DQCI(I)
C-----  ESTABLISH CONTROL NORMALIZATION
C-----  PARAMETERS CK(I) AND CMIN(I)      (RANGES AND MIMINUMS)
        CK(I)   = TOPVKT(I) - BOTVKT(I)
        CMIN(I) = BOTVKT(I)
  480 CONTINUE
C
      CALL PICK(N,C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,QC,CMIN)
C
C*****  NORMALIZE
      DO 490 I=1,N
C
C-----  FIRST, PREPARE FOR PREMATURE ABORT
        QD(I) = QC(I) + CMIN(I)
        QC(I) = QC(I)/CK(I)
  490   QCOLD(I) = QC(I)
C
      CALL PICK(M,S1,S2,S3,S4,S5,S6,S7,S8,S9,S10,TEMTR,DESVKT)
      CALL FILTIT(M,ITFLAG,DESVKT,TEMTR,S)
C
C*****  BEGIN ESTABLISHMENT OF BASIS
      IPARTE = 0
      RETURN
C
C*****  END ONE-SHOT INITIALIZATION ************************
C
C
C*****  WE GET HERE WHEN WE HAVE OUR STATISTICALLY ACCUMULATED STATES
  500 CONTINUE
C
      IF(IPARTE.NE.0) GO TO 580
```

```
C
C*****  AT THIS PRIMARY POINT, BECAUSE MANUAL TERMINATION OF ROUTINE IS
C*****  POSSIBLE, WE ACQUIRE THE CONTROL VECTOR IN SPECIAL CELLS...
C
      DO 510 I=1,N
  510   QD(I) = CK(I)*QC(I) + CMIN(I)
C
C*****  WE ARE AT THE END OF THE CONTROL PRIMARY EVALUATION SEQUENCE
C*****  BECAUSE NK = NDELAY AND IPARTE = 0.
C*****  WE HAVE OBSERVED THE RESULTANT STATES NDELAY TIMES.
C
C*****  PUT THE M STATES INTO THE YZ(I) VECTOR WHEN IPARTE = 0
C*****  YZ(I) TO BE USED AS BASE VALUES FOR FOLLOWING PARTIAL
EVALUATIONS.
C*****  DESIRED YZ(I) = 0.0 BECAUSE BIASES HAVE BEEN TAKEN OUT.
C
      DO 520 I=1,M
  520   YZ(I) = S(I)
C
C*****  DEBUG
C
C*****  ACCEPTANCE  *****
C
C*****  ITRMCM RESETS AUTOMATICALLY IF ACCEPTANCE CRITERIA MET.
C*****  IN THIS CASE TERMINATION OF TRIM IS AUTOMATIC.
C
      IF(IHIT.EQ.0) GO TO 530
C
C-----  GROUND TRIM ACCEPTANCE BASED UPON PBD, QBD, WBD AND VBD
        IF(ABS(S(1)).GT.0.001) GO TO 570
        IF(ABS(S(2)).GT.0.001) GO TO 570
        IF(ABS(S(3)).GT.0.01)  GO TO 570
        IF(ABS(S(4)).GT.0.01)  GO TO 570
C-----  DO NOT DO VARIATION CHECKS
        GO TO 560
C
  530 CONTINUE
C
C*****  AIRBORNE TRIM ACCEPTANCE BASED UPON NORMAL STATE VECTOR (S)
      DO 540 I=1,M
  540   IF(ABS(S(I)).GT.ACPVKT(I)) GO TO 570
C
C*****  NEW VARIATION CHECKS (CONTROLS)
      DO 550 I=1,N
        IF(ABS(QC(I)-QCOLD(I)).LT.ACPCTL) GO TO 550
        IF(IPRONE.EQ.1) THEN
          CALL BTYPE(22,'TRIM:  STATES TRIMMED,')
          CALL BTYPE(39,'TRIM:  WAITING FOR CONTROL QUIESCENCE. ')
          IPRONE = 0
        END IF
        GO TO 570
  550 CONTINUE
C
C*****  AUTOMATIC ACCEPTANCE
```

```
  560 CONTINUE
C
C-----  YOU ARE THROUGH (HERE) WHEN ACCEPTANCE OCCURS AUTOMATICALLY.
C
      IEVAL = 1
      IF(IHIT.EQ.1) THEN
        CALL BTYPE(29,'TRIM:  GROUND TRIM COMPLETED.')
      ELSE
        CALL BTYPE(23,'TRIM:  TRIM COMPLETED. ')
      END IF
      GO TO 420
C
  570 CONTINUE
C
C*****  TRIM IS NOT COMPLETED HERE.
C
C*****  THE TOTAL CONTROL VECTOR'S INFLUENCE ON THE STATE VECTOR
C*****  HAS NOW BEEN OBSERVED FOR NDELAY CYCLES.
C*****  START PERTURBING PARTIALS AGAIN:
C
C*****  SPECIAL - SPECIAL - SPECIAL - SPECIAL
C*****  IREVAL GETS RESET WHEN THE PARTIALS ARE EVALUATED (THEN
INCREMENTED)
C*****  SO, NO MORE PARTIALS UNTIL INCREMENTED IREVAL REACHES KREVAL.
      IF(IREVAL.LT.KREVAL) GO TO 610
C
C*****  BUT, IF YOU MANUALLY SET IT EQUAL TO OR GREATER THAN KREVAL,
C*****  THIS IS THE POINT WHERE WE BEGIN PARTIAL EVALUATIONS AGAIN.
      IPARTE = 1
      GO TO 600
C
C*****  FORM M PARTIALS FOR THIS IPARTE.GT.0 (IPARTE GOES TO N)
C
  580   DO 590 I=1,M
  590     H(I,IPARTE) = (S(I) - YZ(I))/DQC(IPARTE)
C
C*****  AND TAKE OUT THE NORMALIZED CONTROL INCREMENT AT THIS POINT.
C
      QC(IPARTE) = QC(IPARTE) - DQC(IPARTE)
C
C*****  GET NEW DX(I) VECTOR (PRIMARY EVALUATION) ONLY IF IPARTE = N
C
      IF(IPARTE.EQ.N) GO TO 610
C
C*****  INCREMENT IPARTE.  THIS IS A SECONDARY EVALUATION.
      IPARTE = IPARTE + 1
C
C*****  PUT AN INCREMENT IN THIS CONTROL
  600 QC(IPARTE) = QC(IPARTE) + DQC(IPARTE)
      GO TO 990
C
  610 CONTINUE
C
C*****  PRIMARY CONTROL EVALUATION AREA.
```

```
C*****  YOU WILL BE INFORMED NDELAY CYCLES LATER WHEN
C*****  IEVAL WILL BE SET TO UNITY FOR ONE PASS.
C*****  THIS DELAY USED TO LET THE NEWLY COMPUTED CONTROL
C*****  VECTOR PROPAGATE THROUGH YOUR MODEL.
C
C*****  RESET IPARTE FROM N.
      IPARTE = 0
C
C*****  PARTIALS EVALUATED ONLY WHEN IREVAL.GE.KREVAL
      IF(IREVAL.LT.KREVAL) GO TO 920
      IREVAL = 0
C
C*****  DETERMINE REGRESSION TECHNIQUE.
      IF(M.LT.N) GO TO 630
C
C*****  OVERDETERMINED AREA.  (M STATES).GE.(N CONTROLS)
C*****  (MORE STATES THAN CONTROLS (USUAL, E.G. BQUIET))
      NN = N
      DO 620 L=1,N
        DO 620 J=1,N
C*****  FILL OUT BECAUSE OF Z DIMENSION (MAY HAVE ZEROS)
          II = L + MAX*(J-1)
          Z(II) = 0.0
          DO 620 I=1,M
  620       Z(II) = Z(II) + H(I,L)*H(I,J)
C*****  DATA IN Z WILL BE Z(N CONTROLS TIMES N CONTROLS)
C*****  (REQUIRED INVERSION IS ALWAYS THE SMALLER OF NSTATE**2 OR
NCONT**2)
      GO TO 650
C
C*****  UNDERDETERMINED AREA.  M.LT.N
C*****  (LESS STATES THAN CONTROLS)
  630 NN = M
      DO 640 L=1,M
        DO 640 J=1,M
          II = L + MAX*(J-1)
          Z(II) = 0.0
          DO 640 I=1,N
  640       Z(II) = Z(II) + H(L,I)*H(J,I)
C*****  DATA IN Z WILL BE Z(M STATES TIMES M STATES)
C*****  (REQUIRED INVERSION IS ALWAYS THE SMALLER OF NSTATE**2 OR
NCONT**2)
C
  650 CONTINUE
C
C*****  FOR BOTH OVERDETERMINED AND UNDERDETERMINED CASES...
C*****  THE INVERSION PROCESS (NN.NN EQUALS 49 OR 36 OR 16)
C
C     COMPUTE ORDERED AUXILLIARY MATRIX
      N1 = NN - 1
      IF(N1.EQ.0) GO TO 730
      DO 720 I=1,N1
C     ORDER ROWS FOR MAXIMUM Z(I,I)
        IN(I) = 0
```

```
        DET = 0.0
        DO 660 J=I,NN
          I1 = (I-1)*MAX + J
          IF(DET.GE.ABS(Z(I1))) GO TO 660
          IN(I) = J
          DET = ABS(Z(I1))
  660   CONTINUE
        IF(DET.LE.0.0) GO TO 860
        IF(IN(I).EQ.I) GO TO 680
        J = IN(I) - I
        DO 670 K=1,NN
          I1 = (K-1)*MAX + I
          I2 = I1 + J
          DET = Z(I1)
          Z(I1) = Z(I2)
          Z(I2) = DET
  670   CONTINUE
C     COMPUTE ITH ROW
  680   I1 = (I-1)*MAX + I
        DO 700 J=I,N1
          I2 = J*MAX + I
          IF(I.EQ.0) GO TO 700
          DO 690 K=2,I
            I3 = (K-2)*MAX + I
            I4 = J*MAX + K - 1
            Z(I2) = Z(I2) - Z(I3)*Z(I4)
  690     CONTINUE
  700     Z(I2) = Z(I2)/Z(I1)
C     COMPUTE (I+1) ST COLUMN
        DO 710 J=I,N1
          I1 = I*MAX + J + 1
          DO 710 K=1,I
            I2 = (K-1)*MAX + J + 1
            I3 = I*MAX + K
            Z(I1) = Z(I1) - Z(I2)*Z(I3)
  710   CONTINUE
  720 CONTINUE
C
C*****  COMPUTE DETERMINANT OF ORDERED MATRIX
  730 DET = 1.0
      DO 740 I=1,NN
        I1 = (I-1)*MAX + I
        DET = DET*Z(I1)
  740 CONTINUE
C
      IF(DET.EQ.0.0) GO TO 860
C
C*****  COMPUTE GAUSS TRIANGULAR SOLUTION
      DO 770 I=1,NN
        I1 = (I-1)*MAX + I
        Z(I1) = 1.0/Z(I1)
        IF(I.LE.1) GO TO 770
        DO 750 J=2,I
          BB(J) = 0.0
```

```
          DO 750 K=J,I
            I1 = (K-2)*MAX + I
            I2 = (J-2)*MAX + K - 1
            BB(J) = BB(J) - Z(I1)*Z(I2)
  750   CONTINUE
        DO 760 J=2,I
          I1 = (I-1)*MAX + I
          I2 = (J-2)*MAX + I
          Z(I2) = Z(I1)*BB(J)
  760   CONTINUE
  770 CONTINUE
C
C*****  COMPUTE INVERSE
       IF(N1.EQ.0) GO TO 860
       DO 830 I=1,N1
         J = NN - I
         I1 = 1
         DO 820 K=1,NN
           I2 = (K-1)*MAX + J
           GO TO (780,790),I1
  780      BB(K) = Z(I2)
           IF(J-K) 810,800,810
  790      BB(K) = 0.0
  800      I1 = 2
  810      CONTINUE
           DO 820 L=J,N1
             I3 = L*MAX + J
             I4 = (K-1)*MAX + L + 1
             BB(K) = BB(K) - Z(I3)*Z(I4)
  820   CONTINUE
        DO 830 K=1,NN
          I2 = (K-1)*MAX + J
          Z(I2) = BB(K)
  830 CONTINUE
C
C*****  REORDER INVERSE
       DO 850 I=1,N1
         J = NN - I
         K = IN(J)
         IF(K.EQ.J) GO TO 850
         DET = - DET
         DO 840 L=1,NN
           I1 = (J-1)*MAX + L
           I2 = (K-1)*MAX + L
           BB(1) = Z(I1)
           Z(I1) = Z(I2)
           Z(I2) = BB(1)
  840   CONTINUE
  850 CONTINUE
  860 CONTINUE
C
       IF(M.LT.N) GO TO 890
C
C*****  ANOTHER OVERDETERMINED AREA  M.GE.N
```

```
C
      DO 880 I=1,N
      DO 880 J=1,M
      SUM = 0.0
      DO 870 L=1,N
  870 SUM = SUM - Q(I,L)*H(J,L)
      E(I,J) = SUM
  880 CONTINUE
C
      GO TO 920
C
  890 CONTINUE
C
C*****  ANOTHER UNDERDETERMINED AREA  M.LT.N
C
      DO 910 I=1,N
      DO 910 J=1,M
      SUM = 0.0
      DO 900 L=1,M
  900 SUM = SUM - H(L,I)*Q(L,J)
      E(I,J) = SUM
  910 CONTINUE
C
  920 CONTINUE
C
C*****  IREVAL INCREMENTED HERE, AT PRIMARY EVALUATION POINT.
C*****  (THE TRANSITION OF CONTROLS OCCURS AT A PRIMARY EVALUATION
POINT).
      IREVAL = IREVAL + 1
C
      DO 930 I=1,N
        DX(I) = 0.0
        DO 930 J=1,M
  930     DX(I) = DX(I) + E(I,J)*YZ(J)
C
C*****  SEE THE TM IF YOU DO NOT UNDERSTAND THE ABOVE OPERATIONS.
C
C
C*****  XIJK (20) PERCENT MAXIMUM EXCURSION, AND GAIN
C
      DO 950 I=1,N
C-----  SAVING OLD VALUES OF CONTROLS FOR NEW VARIATION CHECK
        QCOLD(I) = QC(I)
        XX = DX(I)*GAIN
        IF(XX.LE.XIJK) GO TO 940
        XX = XIJK
        GO TO 950
  940   IF(XX.GT.(-XIJK)) GO TO 950
        XX = - XIJK
  950   QC(I) = QC(I) + XX
C
      ITBAD = 0
C
C*****  ITBAD.NE.0 INFORMS THE USER THAT HE HAS HIT A CONTROL LIMIT
```

```
C*****  DURING A PRIMARY EVALUATION.
C*****  IN THIS CASE SUBROUTINE TRIM BACKS THE CONTROL OFF BY 5 PERCENT
C*****  OF THE RANGE (DEFINED AS MAX - MIN).
C
      DO 980 I=1,N
C
        XY = QC(I)
        IF(XY.GT.0.0) GO TO 960
        QC(I) = 0.05
        ITBAD = - I
        GO TO 970
  960   IF(XY.LT.1.0) GO TO 980
        QC(I) = 0.95
        ITBAD = I
C
  970   CONTINUE
C
C-----  THE VALUE OF ITBAD SHOWS WHICH CONTROL, THE SIGN SHOWS THE
SENSE.
C
        IF(ITBAD.GT.0) THEN
          ITBADU(I)=1
        ELSE
          ITBADL(I)=1
        END IF
C
C
  980 CONTINUE
C
      KMESS=KMESS + 1
C
        IF(KMESS .LT. NMSGTR)  GO TO 985
        DO 983 K=1,N
C
        IF(ITBADU(K) .NE. 0) THEN
         ITBADU(K)=0
         AMESGU(K)= 'TRIM:  CONTROL '//NUM(K)//' HAS HIT UPPER LIMIT.  '
         CALL BTYPE(40,AMESGU(K))
        ENDIF
C
        IF(ITBADL(K) .NE. 0) THEN
         ITBADL(K)=0
         AMESGL(K)= 'TRIM:  CONTROL '//NUM(K)//' HAS HIT LOWER LIMIT.  '
         CALL BTYPE(40,AMESGL(K))
        ENDIF
C
C
  983 CONTINUE
      KMESS=0
  985 CONTINUE
C
C
  990 IF(IHIT.EQ.0) GO TO 1000
C
```

```
C*****  SPECIAL CONTROL VECTOR IF IHIT = 1
      THETIC = QC(1)*CK(1) + CMIN(1)
      HIC    = QC(2)*CK(2) + CMIN(2)
      PHIIC  = QC(3)*CK(3) + CMIN(3)
      GO TO 1110
C
 1000 CONTINUE
C
C*****  CHANGE THE USERS CONTROL VECTOR (CALLING SEQUENCE VARIABLES)
C
      GO TO (1100,1090,1080,1070,1060,1050,1040,1030,1020,1010),N
C
 1010 C10 =  QC(10)*CK(10) + CMIN(10)
 1020 C9  =  QC(9)*CK(9)   + CMIN(9)
 1030 C8  =  QC(8)*CK(8)   + CMIN(8)
 1040 C7  =  QC(7)*CK(7)   + CMIN(7)
 1050 C6  =  QC(6)*CK(6)   + CMIN(6)
 1060 C5  =  QC(5)*CK(5)   + CMIN(5)
 1070 C4  =  QC(4)*CK(4)   + CMIN(4)
 1080 C3  =  QC(3)*CK(3)   + CMIN(3)
 1090 C2  =  QC(2)*CK(2)   + CMIN(2)
 1100 C1  =  QC(1)*CK(1)   + CMIN(1)
C
 1110 CONTINUE
C
C
C*****  CALL TAKEN OUT, SUFFER THY CYCLE DELAY, THOU NON-STRIKE USERS!
C*****  (SEE ABOVE LENGTHY MESSAGE).
C     CALL STRIKE
C
      RETURN
      END
C
C
C
C
C
C234567890123456789012345678901234567890123456789012345678901234567890
C        1         2         3         4         5         6         7
C
C
      SUBROUTINE PICK(NV,V1,V2,V3,V4,V5,V6,V7,V8,V9,V10,VEK,DD)
C
C
C
C**********************************************************************
C                  SUBROUTINE ABSTRACT & HIERARCHY
C**********************************************************************
C
C     ONE WAY TO MAKE A VECTOR (MINUS BIASES) FROM SCALARS.
C
C
C
C**********************************************************************
```

```
C                  CREATION & MODIFICATION LOG
C*********************************************************************
C       DATE   INIT DOC#                    DESCRIPTION
C   ------------------------------------------------------------------
C
C     07/20/89  REM  CREATED
C
C
C
C*********************************************************************
C                  D E C L A R A T I O N S
C*********************************************************************
C
      DIMENSION VEK(10),DD(10)
C
C
C
C
C*********************************************************************
C                  E X E C U T A B L E    C O D E
C*********************************************************************
C
      GO TO (1,2,3,4,5,6,7,8,9,10),NV
  10  VEK(10) = V10 - DD(10)
   9  VEK(9)  = V9  - DD(9)
   8  VEK(8)  = V8  - DD(8)
   7  VEK(7)  = V7  - DD(7)
   6  VEK(6)  = V6  - DD(6)
   5  VEK(5)  = V5  - DD(5)
   4  VEK(4)  = V4  - DD(4)
   3  VEK(3)  = V3  - DD(3)
   2  VEK(2)  = V2  - DD(2)
   1  VEK(1)  = V1  - DD(1)
C
C
      RETURN
      END
C
C
C
C
C
C234567890123456789012345678901234567890123456789012345678901234567890
C        1         2         3         4         5         6         7
C
C
      SUBROUTINE FILTIT(K,ITFLAG,DESVKT,V,F)
C
C
C
C*********************************************************************
C                  SUBROUTINE ABSTRACT & HIERARCHY
C*********************************************************************
C
```

```
C     INPUT V VECTOR, OUTPUT F VECTOR, FILTERED VALUES.
C
C
C
C*********************************************************************
C                  C O M M O N S
C*********************************************************************
C
      COMMON/XFLOAT/A(500)/IFIXED/IA(250)
      COMMON /FEXTRA/FEXT(20)
C
C
C
C*********************************************************************
C                  D E C L A R A T I O N S
C*********************************************************************
C
      DIMENSION VP(10),V(*),F(*),DESVKT(*)
C
      SAVE NDP,VP,EAT,EV1,EV2
C
C
C
C*********************************************************************
C                  E Q U I V A L E N C E S
C*********************************************************************
C
      EQUIVALENCE (IA( 46), NDELAY)
C
C
C
C*********************************************************************
C                  D A T A    I N I T I A L I Z A T I O N
C*********************************************************************
C
      DATA NDP/-1/
C
C
C
C
C*********************************************************************
C                  E X E C U T A B L E    C O D E
C*********************************************************************
C
        IF(ITFLAG.EQ.0) GO TO 20
        IF(NDELAY.EQ.NDP) GO TO 40
  20    NDP = NDELAY
C
C*****  TO TELL FILTIT THAT YOU'VE BEEN HERE BEFORE THIS TRIM ATTEMPT.
        ITFLAG = 1
C
C*****  TIME CONSTANT TAU = NDELAY*DT/4
        DO 30 I=1,K
          F(I) = V(I)
```

```
  30      VP(I) = V(I)
C
C*****  TRIANGULAR-ORDER HOLD.  DO NOT CHANGE ORDER OF SENSITIVE EQNS.
        AT = 4.0/NDELAY
        EAT = EXP(-AT)
        EVX = (1.0 - EAT)/AT
        EV1 = 1.0 - EVX
        EV2 = EVX - EAT
C
C*****  FILTER THE OUTPUT
  40  DO 50 I=1,K
        F(I) = EAT*F(I) + EV1*V(I) + EV2*VP(I)
        FEXT(I) = F(I) + DESVKT(I)
        VP(I) = V(I)
  50  CONTINUE
C
C
      RETURN
      END
```